JOURNAL of ECONOMIC ENTOMOLOGY

UNIVERSITY OF MICHIGAN
JAN 12 1955
FORESTRY LIBRARY

Published by the
ENTOMOLOGICAL SOCIETY OF AMERICA
Formed in 1953 by Consolidation of the
American Association of Economic Entomologists
(1889-1952)
and the former
Entomological Society of America (1906-1952)

Formerly Published by the
AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

DECEMBER • 1954

Volume 47 Number 6

JOURNAL OF ECONOMIC ENTOMOLOGY

Published by
ENTOMOLOGICAL SOCIETY OF AMERICA

F. W. Poos, *Editor*, 1530 P St., N.W., Washington 5, D.C.

Ashley B. Gurney, *Executive Secretary*, 1530 P. St., N.W., Washington 5, D.C.

PUBLICATIONS BOARD

E. L. Chambers, *Chairman*, Madison, Wis. Term Expires 1954

R. L. Metcalf, Riverside, Calif. Term Expires 1955

D. E. Howell, Stillwater, Okla. Term Expires 1956

G. E. Bohart, Logan, Utah. Term Expires 1957

F. S. Arant, Auburn, Ala. Term Expires 1958

A bimonthly journal published on the 15th of February, April, June, August, October and December, devoted to the interests of economic entomology and publishing the official notices and proceedings of the Entomological Society of America.

TERMS OF SUBSCRIPTION. To members of the Entomological Society of America in continental U.S.A. and its possessions $4.00. Members outside of the U.S.A.—$4.50. Non-members in the U.S.A., Cuba, Mexico and Canada—$10.00. Non-members in other countries—$10.00 plus 60¢ postage. Single copies $1.75 plus postage of 10¢ per copy.

BUSINESS COMMUNICATIONS of the Society and SUBSCRIPTIONS AND ADVERTISEMENTS to the Journal should be sent to the Executive Secretary, Ashley B. Gurney, 1530 P. St., N.W., Washington 5, D.C.

MANUSCRIPTS and other copy for the Journal as well as all correspondence concerning Journal content, should be addressed to the editor, F. W. Poos, 1530 P St., N.W., Washington 5, D.C.

CHANGE OF ADDRESS must reach the office of the Executive Secretary 45 days prior to the month of issue to be effective for that month.

Entered as second class matter at the Post Office at Menasha, Wisconsin. Acceptance for mailing at special rate of postage under the provisions of Sec. 34-40, Par. (D), provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. and R., authorized May 1, 1936.

Printed in U.S.A.

ISSUED DECEMBER 24, 1954

JOURNAL OF ECONOMIC ENTOMOLOGY
ENTOMOLOGICAL SOCIETY OF AMERICA
Formerly Official Organ American Association of Economic Entomologists

Vol. 47 December, 1954 No. 6

CONTENTS

Ecological and Nutritional Studies on the Cherry Fruit Fly...ADEL S. KAMAL 959
Equipment and Technique Used in Laboratory Evaluation of Pesticide Dusts in Toxicological Studies with Honeybees.....E. L. ATKINS, JR., L. D. ANDERSON AND T. O. TUFT 965
Toxicity of Pesticide Dusts to Honeybees.....E. L. ATKINS, JR., AND L. D. ANDERSON 969
Distribution of Radioactive Phosphorus in Susceptible and Resistant House Flies.....FRANK H. BABERS AND C. C. ROAN 973
Laboratory Studies on Factors Influencing the Efficiency of Insecticide Impregnated Cords for House Fly Control.R. W. FAY AND DONALD A. LINDQUIST 975
Are Cotton Insects Becoming Resistant to Insecticides?.....E. E. IVY AND A. L. SCALES 981
Correlation Between the Length of the Larval Period of *Musca domestica* L. and Resistance of Adult Flies to Insecticides.....R. E. MCKENZIE AND W. M. HOSKINS 984
Insecticide Tests with Cabbage Caterpillars and Aphids.....L. E. DILLS AND M. L. ODLAND 992
The Frequency of Multiple Mating of Queen Honey Bees.STEPHEN TABER, III 995
House Fly Control in Dairies Near Savannah, Georgia, with Residual Applications of CS-708, NPD, and Malathion.....JOHN W. KILPATRICK AND H. F. SCHOOF 999
The Tomato Russet Mite in the United States.....LAUREN D. ANDERSON 1001
A Power-Driven Self-Propelled Soil Sifter for Subterranean Insects.....W. H. LANGE, N. B. AKESSON AND E. C. CARLSON 1006
Distribution of Third Instar Larvae of the European Chafer and the Efficiency of Various Sampling Units for Estimating Their Populations.....R. H. BURRAGE AND GEORGE G. GYRISCO 1009
The Effects of the Second Generation European Corn Borer on Field Corn...H. C. CHIANG, L. K. CUTKOMP AND A. C. HODSON 1015
Summer Control of Pear Leaf Blister Mite.....H. P. LANCHESTER 1020
Tests of the Dielectric Treatment of Cotton Seed for Destroying Pink Bollworms.....W. L. LOWRY, A. J. CHAPMAN, F. T. WRATTEN AND J. P. HOLLINGSWORTH 1022
Subunits of Sample for Estimating Aphid Abundance on Potatoes.....W. A. SHANDS, G. W. SIMPSON AND L. B. REED 1024
Residues of *p*-Chlorophenyl-*p*-Chlorobenzenesulfonate (*Compound K-6451*) on and in Lemons and Oranges.....F. A. GUNTHER AND L. R. JEPPSON 1027
Harvest Residues of Apparent Dieldrin in Peel and Juice of Navel Oranges...F. A. GUNTHER, J. H. BARKLEY AND W. H. EWART 1033
Some Ecological Aspects of the Resistance of Crop Plants to Insects.....REGINALD H. PAINTER 1036
Effect of Certain Insecticides and Fungicides on Plant Emergence and Control of the Seed-Corn Maggot.....M. H. FROST, JR., L. D. ANDERSON AND J. C. ELMORE 1040

The Behavior of Systox-Isomers in Bean and Citrus Plants. . . . . R. L. METCALF, R. B. MARCH, T. R. FUKUTO AND MARION MAXON 1045
Hazards Involved When Animals are Exposed to Organic Insecticidal Residues. . . . . DWIGHT M. DELONG AND PAUL LUDWIG 1056
The Adsorption, Distribution, and Site of Action of DDT in DDT-Resistant and DDT-Susceptible House Flies Using Carbon[14] Labelled DDT. . . . . E. J. LEROUX AND F. O. MORRISON 1058
The Synthesis and Chromatographic Purification of Radioactive Allethrin. . . . . FRED ACREE, JR., C. C. ROAN AND FRANK H. BABERS 1066
Seasonal Incidence of Fleas on the California Ground Squirrel in Orange County, California. . . . . RAYMOND E. RYCKMAN, ... CHESTER C. LINDT, CHARLES T. AMES AND ROBERT D. LEE 1070
Studies with *Bacillus thuringiensis* in Relation to the European Corn Borer. . . . . ELLICOTT MCCONNELL AND L. K. CUTKOMP 1074
Subchronic Toxicity of Four Chlorinated Dimethanonaphthalene Insecticides to Chicks. . . . . MARTIN SHERMAN AND MORTON M. ROSENBERG 1082
Life History and Habits of *Tetranychus desertorum* and *bimaculatus* on Cotton . . . . . WILLIAM IGLINSKY, JR. AND C. F. RAINWATER 1084
Milky Diseases of European Chafer Larvae. . . . H. TASHIRO AND R. T. WHITE 1087
Field Evaluation of Insecticides Against Codling Moth. . . . . E. H. GLASS 1093
Dichloropropane-Dichloropropene Mixtures of Different Composition as Soil Fumigants in Pineapple Land. . . . . WALTER CARTER 1101
A Laboratory Apparatus for Determining Repellency of Pyrethrum When Applied to Grain. . . . . HAMILTON LAUDANI AND G. R. SWANK 1104
The Effects of Red, White, and South American Cedar Chests on the Various Stages of the Webbing Clothes Moth and the Black Carpet Beetle. . . . . HAMILTON LAUDANI AND P. H. CLARK 1107
Effect of Systemic Insecticides Upon Certain Peanut Insects and Upon Peanuts . . . . . B. WAYNE ARTHUR AND F. S. ARANT 1111
Soil Application of Insecticides to Control Plum Curculio. . . . . C. L. FLUKE AND D. A. DEVER 1115
Aphid Collections in the Yakima Valley of Washington, 1947–53. . . . . E. W. DAVIS, B. J. LANDIS AND K. E. GIBSON 1117
Aphid Transmission of a Bean Yellow Mosaic Virus. . . . . K. G. SWENSON 1121
Control of Corn Earworm and Stored Grain Insects in Single-Cross Corn. . . . . W. G. EDEN 1124
Insects Associated with Salt Cedar in Southern Arizona. . . . . LEMAC HOPKINS AND L. A. CARRUTH 1126
Application Schedules for Control of Cotton Insects. . . . . R. L. HANNA 1129
Malathion and Malathion-Parathion Sprays for Control of the Soft Scale on Citrus in California. . . . . H. S. ELMER AND W. H. EWART 1131
An Adaptation of Commercial Shearing Equipment for Sampling Range Vegetation. . . . . E. J. HINMAN 1133
Biological and Toxicological Studies of the Little House Fly. . . . . LAWRENCE L. LEWALLEN 1137
Control of the Pepper Weevil. . . . . JOHN C. ELMORE AND ROY E. CAMPBELL 1141

SCIENTIFIC NOTES:

First Report of the Poultry Bug from a Golden Eagle's Nest, with New Locality Records. . . . . ROBERT D. LEE 1144
Use of Wettable Powder or Emulsion Formulations Compared with Mineral Seal Oil on Calves. . . . . W. G. HOEKSTRA, R. J. DICKE AND P. H. PHILLIPS 1144
Cuterebra lepivora Reared from *Sylvilagus audubonii sanctidiegi* in San Bernardino County, California. . . . . RAYMOND E. RYCKMAN AND CHESTER C. LINDT 1146
Three New Phosphate Insecticides for the Systemic Control of Cotton Insects. . . . . E. E. IVY, A. L. SCALES AND L. J. GORZYCKI 1148
A New Pest of Cotton in Texas. . . . . D. F. MARTIN AND W. J. MISTRIC, JR. 1149

The Red-Headed Ash Borer in Idaho ..... WILLIAM F. BARR AND H. C. MANIS 1150
Control of the Strawberry Weevil in Blackberries ..... W. G. EDEN 1150
Grasses as Hosts of the Greenbug ..... R. G. DAHMS, R. V. CONNIN AND W. D. GUTHRIE 1151
The Effectiveness and Limitations of Homemade Self-Treatment Rubbing Devices for Louse Control on Cattle ..... ROBERT A. HOFFMAN 1152
Techniques for Testing the Attachment and Feeding Rate of Mites on Living Hosts ..... H. F. CROSS AND G. W. WHARTON 1153
Feeding Tests with Blood Sucking Mites on Heparinized Blood ..... H. F. CROSS 1154
Control of the Sugarcane Beetle in Corn ..... W. G. EDEN 1155
Control of Army Cutworms ..... C. C. BURKHARDT 1156
The Yellow Clover Aphid—A New Alfalfa Pest in the Southwest ..... D. M. TUTTLE AND G. D. BUTLER, JR. 1157
Effect of Planting Date on Corn Earworm Damage to Dent Corn ..... W. A. DOUGLAS 1158

EDITORIAL: Systematic Entomology—Retrospect and Prospect 1159

OBITUARIES:

Harry F. Dietz 1162
Sherman Weaver Bilsing 1163
Herbert Osborn 1164

BOOK REVIEWS 1158, 1165

INDEX XII TO THE LITERATURE OF AMERICAN ECONOMIC ENTOMOLOGY IS NOW AVAILABLE

Index XII, covering 1952 Literature of American Economic Entomology, is now ready for distribution. This is a volume of 321 pages, bound in impregnated, insect repellent cloth.

The price of this volume to members of the Entomological Society of America in the United States, its territories, and Canada is $2.00 postpaid. The price to members of the Society in all other countries is $2.00 plus 50¢ for postage and handling.

The price of this volume to *non-members* of the Society in all countries is $3.00 postpaid.

In addition to Index XII, the following volumes of the series, Index to the Literature of American Economic Entomology, are now available:

Index No.	*Years Covered*	*Year Published*	*Price to Members*	*Price to Non-Members*
I	1905–14	1917	$5.00	$5.00
II	1915–19	1921	4.00	4.00
III	1920–24	1925	4.00	4.00
IV	1925–29	1930	4.00	4.00
V	1930–34	1938	4.50	4.50
VI	1935–39	1941	6.00	6.00
VII	1940–44	1948	4.00	7.00
VIII	1945–47	1951	4.00	7.00
IX	1948–49	1954	3.00	3.50
X	1950	1952	1.50	2.00
XI	1951	1953	1.50	2.00

The above prices are all postpaid. All the volumes are cloth bound with the exception of Index X, which is available in paper cover only. A discount of 25% is allowed to members of the Society on orders for complete sets, Index I through Index XII. On orders for three or more volumes, but less than a complete set, members are allowed a 10% discount. These discounts are not allowed to non-members.

Orders should be sent to the Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C., U.S.A. Drafts, checks or money orders should be made payable to the Entomological Society of America.

JOURNAL OF ECONOMIC ENTOMOLOGY
ENTOMOLOGICAL SOCIETY OF AMERICA
Formerly Official Organ American Association of Economic Entomologists

Vol. 47 December, 1954 No. 6

Ecological and Nutritional Studies on the Cherry Fruit Fly[1]

ADEL S. KAMAL,[2,3] *Washington Agricultural Experiment Stations, Pullman*

The cherry fruit fly, *Rhagoletis cingulata* (Loew), is by far the most destructive pest of cherry fruit in eastern Washington. In spite of the use of modern insecticides, each year some growers obtain inadequate control of the fruit fly, which results in contamination and loss of fruit at harvest time. The main reasons for this situation are improper timing and/or insufficient number of applications of insecticides. The key to this problem lies in a more precise knowledge of the biology of the pest.

The general life cycle of the cherry fruit fly is well known. Seasonal development, including the lengths of time required for development of the various stages, has been presented by Caesar & Spencer (1915), Frick (1949), and Cox (1952). The recent report of Frick *et al.* (1954) is the most complete treatise on bionomics, taxonomic status, distribution, and control of the cherry fruit flies in the Pacific Northwest region.

The critical points in the life history of the cherry fruit fly, in regard to its control, are the preoviposition and oviposition periods. The following studies were conducted in an attempt to establish the effects of gross nutritional requirements and temperatures upon egg development and deposition.

MATERIALS AND METHODS.—Four temperature cabinets were maintained at 90°, 80°, 70°, and 65° F. $\pm 1°$ F. These were equipped with white fluorescent lights[4] which provided a light intensity of 100-foot candles on the upper trays and 10-foot candles on the midle trays. The lights burned continuously throughout the experiment (except for test Z where flies were kept in complete darkness). Humidity was maintained by using flat pans filled with water placed in front of fans at a level sufficient to keep the cotton pads on top of the rearing cages continually moist.

The adults were maintained in cages consisting of standard glass lamp chimneys. The tops were covered with 32-mesh, natural-color, plastic screening[5] and the chimneys were placed on petri dishes. A pad of cotton nearly the diameter of the chimney top was dampened once a day and placed on top of the cages to provide moisture. Casein and yeast hydrolysate were provided in small Syracuse watch glasses, while sugar cubes were placed directly on the petri dishes. Uninfested cherries obtained from branches previously protected with screen sleeve cages were placed on the petri dishes. In all tests except test E, a cherry was not placed in a cage until copulation was first noticed in that cage. Then cherries were changed daily thereafter. In test E, a cherry was provided from the start. The cherries were not pre-cooled before being placed at 70° or 65° F. The media used in the various sets of experiments are listed in table 1 and are referred to in the test by their appropriate letter designations.

After removal from the cages, each cherry was placed in a pint frozen food carton and maintained in the laboratory at $77° \pm 2°$ F.

The flies were collected from cages placed over naturally-infested soil. The flies were usually not more than 8 and never more than 12 hours old when placed in the cages. Five flies of each sex were placed in

[1] Scientific Paper No. 1309, Washington Agricultural Experiment Stations, Pullman, Project No. 791.

[2] Research Assistant in Entomology, Washington State College, Pullman.

[3] The author wishes to express his thanks to the Washington State Fruit Commission for financial assistance and to Drs. H. S. Telford, M. T. James, M. Rockstein, C. A. Johansen and H. G. Simkover for their helpful suggestions and critical readings of the manuscript.

[4] Daylight, 15 watt, Westinghouse.

[5] *Lumite*, Lumite Division, Chicopee Manufacturing Corporation of Georgia, Buford, Georgia.

Table 1.—Observations on the cherry fruit fly under different temperatures and diets at a light intensity of 100 foot-candles. Prosser, Wash. 1952–1953.

Temperature Degrees F.	Test	Diet	Emergence to First Copulation (Days)	Pre-oviposition Period (Days)	Time for 50% Mortality (Days)	Pairs in Copulation from Emergence to 50% Mortality	Additional Pairs in Copulation 50%–100% Mortality	Period of Mating Activity (Days)	Oviposition Period (Days)	Time for 100% Mortality (Days)
90	A	H_2O+sugar	5	7	10	4	2	1	1	25
	B	H_2O+sugar+yeast	4	—	9	1	0	1	0	14–
	C	H_2O+sugar+casein	7	10	10	3	0	3	1	19
80	D	H_2O+sugar	5	8	25	44	1	30	36	64
	E	H_2O+sugar+cherry from start	4	8	18	42	8	25	34	44
	F	H_2O+sugar+casein	5	8	29	52	1	30	34	73
80	Y[1]	H_2O+sugar+yeast	5	9	23	19	3	21	31	91
	Z[2]	H_2O+sugar	11	12	42	26	0	31	35	94
70	G	H_2O+sugar	8	9	23	9	0	9	14	40
	H	H_2O+honey	4	7	21	17	7	32	32	60
	I	H_2O+sugar+casein	9	10	20	9	1	5	13	46
65	J	H_2O+sugar	6	7	13	10	2	10	13	34
	K	H_2O+sugar+yeast	8	12	17	16	8	15	14	32–
	L	H_2O+sugar+casein	8	11	22	11	0	12	9	47

[1] Held at a light intensity of 10 foot-candles.
[2] Held in total darkness except for a daily feeding period of 10 minutes.

each cage. Each treatment consisted of five cages or a total of 50 flies.

General Observations.—The behavior of the flies was observed as much as possible. In general, the flies behaved no differently from those in the orchard. At 90° F., the flies were relatively sluggish and inactive as compared with those kept at lower tempratures. Flies in the orchard also became inactive and hung nearly motionless during periods with temperatures of more than 90° F. The caged flies kept in complete darkness (Test Z, Table 1) became very agitated when exposed to light during watering periods. They walked and flew more rapidly than those taken from the other cabinets, fluttering their wings constantly, and making short, rapid flights.

Adult Life Span.—The longevity under orchard conditions is not known exactly. The data obtained from these studies show considerable variation at different temperatures (Table 1). At 90° F., 50 per cent of the flies died within 9–10 days, regardless of sex and diet. In this group, two females lived 25 and 19 days, respectively. The longevity of males appeared to be somewhat less, with only four males reaching an age of 18 days. In general, most flies died during the second week of adult life. The high humidity in the 90° F. cabinet contributed to the high rate of mortality in a mechanical way. The sugar cubes deliquesced and became sticky much more rapidly than at 80°, 70°, or 65° F., and the flies were trapped as they came into contact with this sticky material. At 90° F. only 10 pairs were seen in copula and only two females laid eggs—one in group A and one in group C. The eggs of both females failed to hatch.

When yeast was provided the flies lived for slightly shorter periods than the flies of the corresponding tests at the same temperature. Fecundity also was considerably increased. At 65° F., up to the time of 100 per cent mortality, 24 pairs were seen in copulo as compared with 12 and 11 pairs for test J and L, respectively. Uvarov (1928) indicated that protein is generally essential for reproduction and development of eggs in insects. He also indicated that nitrogen shortens the life span of the individual somewhat in comparison with an exclusive carbohydrate diet. If this is true, it is logical to conclude that yeast could be considered a source of nitrogen in addition to being a good source of vitamins. The exception to this observation was test Y where, although flies were fed on a yeast diet, the longevity was increased and the fecundity was decreased in comparison with the other tests at the same temperature. This might be attributed to light intensity, since flies of this test were subjected to 10-foot candles of light as compared with 100-foot candles in the remaining groups. The effect of light is more pronounced in test Z where

Table 2.—Egg development in female flies subjected to various constant temperatures. Prosser, Wash. 1952–1953.[1]

TEMPERATURE, °F.	90°	80°	70°	60°
	Flies 10 days old			
Total flies	14	12[2]	9	17
Flies with fully developed eggs	9	11	9	3
Per cent with eggs	64.3	91.6	100	17.6
Total eggs	34	134	100	14
Average No. eggs per fly	2.4	11.2	11.1	0.8
	Flies 12 days old			
Total flies		4	5	8
Flies with fully developed eggs		4	5	5
Per cent with eggs		100	100	62.5
Total eggs		66	50	21
Average No. eggs per fly		16.5	10	2.6

[1] From Frick (unpublished data).
[2] Eggs first deposited when flies 8 days of age.

flies were kept in complete darkness. The flies in this test lived longer than those in any other test, even though they were fed only water and sugar. Ninety-four days were required for 100 per cent mortality as compared with 64 days for flies reared on the same diet and at the same temperature.

When casein was provided, longevity generally was increased in comparison with corresponding tests at the same temperature. One exception was a female which lived 25 days at 90° F. and was fed only water and sugar. Another exception was test H where feeding the flies water and honey increased the life span considerably. Honey seemed to increase the fecundity, since 17 pairs were recorded in copula compared with 9 pairs for other tests (G and I) at 70° F. Longevity also was considerably increased by providing honey. Sixty days were required for 100 per cent mortality, whereas 40 days were required when sugar alone was provided.

COPULATION.—It was not possible to maintain an oviposition record for individual females, owing to the relatively large number of tests involving many flies in separate cages. For the same reason, no studies were conducted on the length of time of each copulation or the number of copulations during a lifetime. Such data would have required frequent opening of the cabinets, causing fluctuations in temperature and humidity. Copulation was recorded when noticed while the flies were being cared for. It occurred in all cases 1 to 4 days before the first eggs were laid. Often a pair remained together for a number of hours. The data presented in table 1 show that 80° F. was the optimum temperature for mating activity. However, the maxium period of 32 days was obtained at 70° F. It was materially decreased at 90°F. and considerably affected at 70° F. and 65° F.

Preoviposition Period.—The establishment of the preoviposition period is highly significant if any control measure for the cherry fruit fly is to be effective. It has been reported in the literature that the preoviposition period requires about 10 days (Ceasar & Spencer 1915, Cox 1952) or 2 weeks (Illingworth 1912). Frick (1949) reported that a few eggs were laid on the seventh day after emergence under laboratory conditions. The results of this study confirmed the latter's findings. As shown in table 1, there were three instances where eggs were laid on the seventh day. In only one case, test H, did the eggs develop into larvae. In the remaining two tests (A and J) the eggs appeared to be infertile, since none hatched. The first fertile eggs were those laid in test J 10 days after emergence. These data also show that the length of the preoviposition period tended to increase as the temperature decreased.

EGG DEVELOPMENT.—Several preseason tests, using flies emerging from pupae held at 32° to 40° F. for 5 months, were conducted by Frick *et al.* (1954) in an attempt to determine the effect of temperature on egg development. These tests were delayed until early May so that the

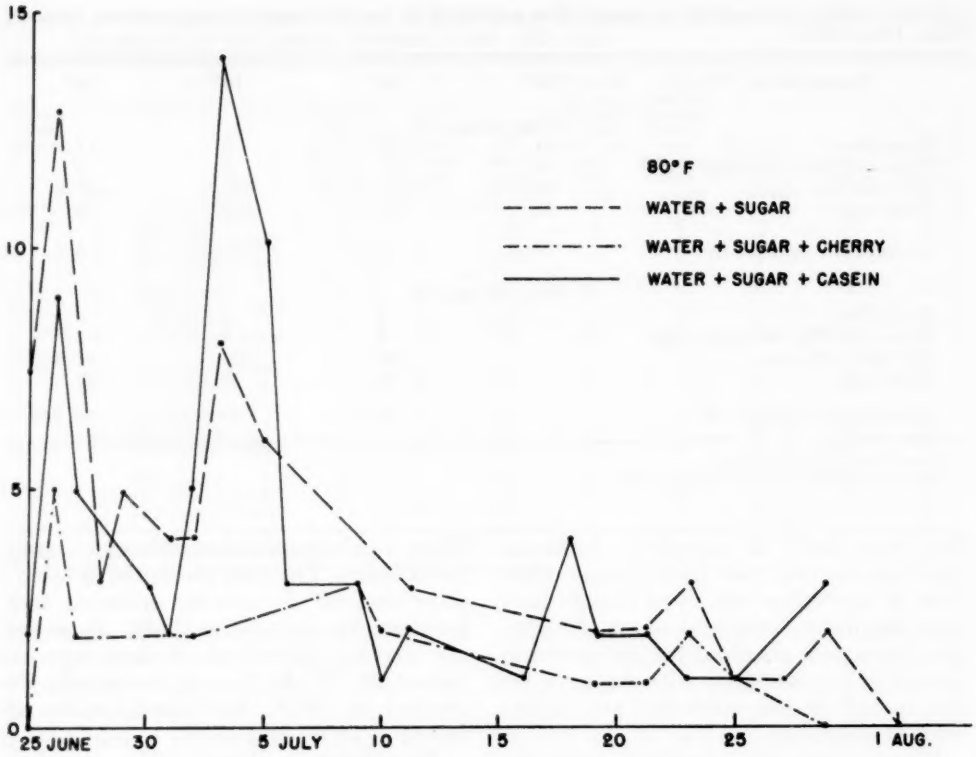


FIG. 1.—The effect of temperature upon fecundity of the cherry fruit fly. The axis represents the number of pupae. 1952–1953.

cherries used as the medium for egg deposition would be at least half-grown. The pits had hardened by the time the flies were 8 days old, although the fruits were only $\frac{1}{2}$ inch in diameter. For this test the lights were turned on at 8 A.M. and off at 5 P.M. each day. The flies were 4 to 8 hours old when placed in the cabinets. They were fed by soaking cotton pads nearly the diameter of the lamp chimney tops in 10 per cent sucrose solution and placing these on the screen tops. Cherries were provided daily, two per cage, each with the stem in a vial of water. Feeding punctures were found on the fruit when the flies were 6 days old. However, no eggs

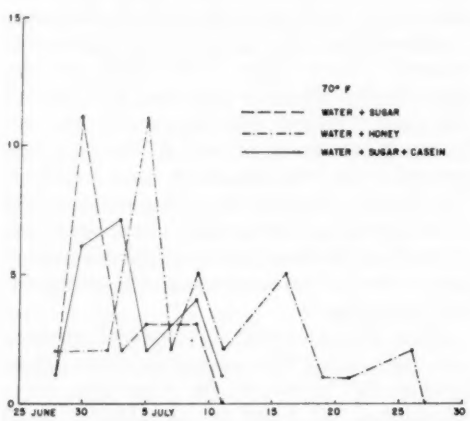


FIG. 2.—The effect of temperature upon fecundity of the cherry fruit fly. The axis represents the number of pupae. 1952–1953.

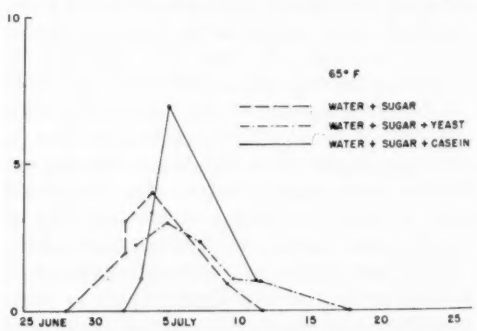


FIG. 3.—The effect of temperature upon fecundity of the cherry fruit fly. The axis represents the number of pupae. 1952–1953.

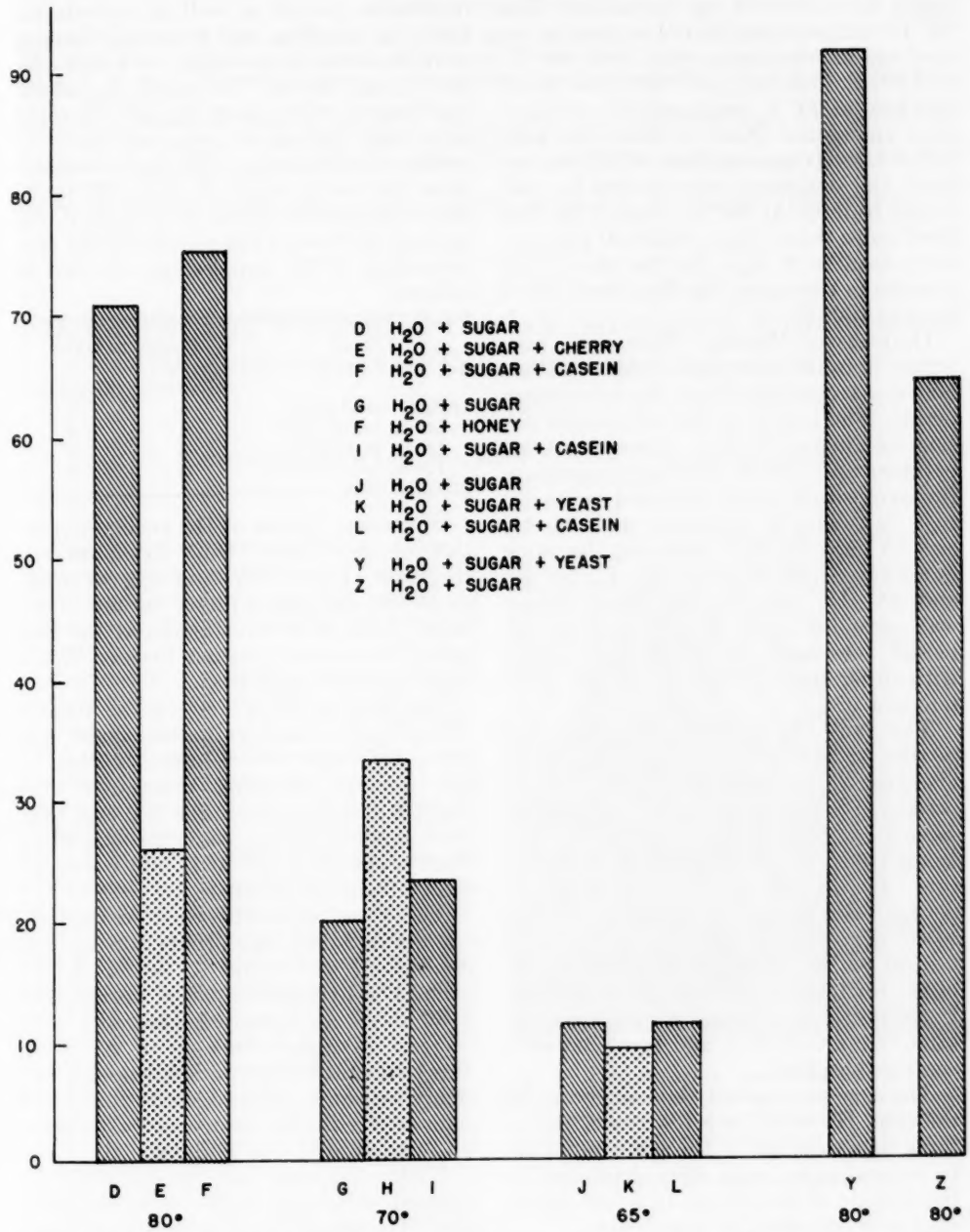


FIG. 4.—The effect of temperature and light intensity on egg production of the cherry fruit fly expressed in total number of pupae obtained from a given test. All tests were kept at 100 foot-candles except for test Y which was kept at 10 foot-candles and test Z which was kept at total darkness except for a daily feeding period of 10 minutes. 1952–1953.

were found until the flies were 8 days old.

Females held for 10 and 12 days at constant temperatures following emergence were dissected and their ovaries examined for fully developed eggs. Data presented in table 2 indicate that 80° F. was the optimum temperature for egg development. Although flies at 70° F. and 80° F. had almost an equal number of eggs in their ovaries, eggs were deposited only by females kept at 80° F. It is possible that the degree of maturity of the cherries

might have affected egg deposition. The 70° F. temperature did not appear to retard egg development, while both 90° F. and 60° F. definitely did. Only one lot of flies held at 90° F. remained alive 10 days after emergence. None of these was held for 12 days. It appears that 90° F. was beyond the optimum temperature for the cherry fruit fly. At 100° F., none of the flies lived more than 5 days, while 50 per cent were dead in 2 days. In the absence of cherries in the cages, the flies lived only 2 days at 100° F.

OVIPOSITION PERIOD.—The data presented in table 1 also show the correlation between temperature and the oviposition period. The length of the oviposition period was increased with increase in temperature up to 90° F. At this temperature the oviposition period dropped suddenly to 1 day. This is compared with 36, 14, and 13 days for flies receiving the same diet (water and sugar) at 80° F., 70° F., and 65° F., respectively. When honey was provided (test H), the oviposition period increased measurably compared with other tests (G and I) at the same temperature.

The daily egg production is expressed by the number of pupae resulting from given egg deposition dates. These data are presented in figures 1, 2, and 3. Given the same diet, female productivity was decreased with each decrease in temperature. This is shown clearly in figure 4. Seventy-one were obtained from test D where flies were fed water and sugar and held at 80° F., compared with 20 and 11 pupae for tests G and J at 70° F. and 65° F., respectively. Similar results were obtained from tests F, I, and L, when casein was also provided.

The eggs were usually laid singly under the skin. However, in a few cases, two or three eggs were laid in the same puncture. In several cases, eggs were deposited on the outside of the cherry. In a few others, eggs were deposited on sugar cubes.

INCUBATION PERIOD.—There was little difference in the incubation period of eggs deposited under different temperatures in the laboratory, since all cherries containing eggs were held at room temperature (77° F. $\pm$ 2°). In all of the tests the incubation periods varied from 5 to 8 days.

DEVELOPMENT.—The larval development was observed at 24-hour intervals. Cherries were examined daily under a binocular microscope to determine the incubation period as well as various instars. As hatching was detected, cherries were dissected in an effort to locate the developing larvae. In many instances, particularly when observing for the early first stage larvae, it was necessary to employ the binoculars. The data obtained show the wide range of time (13 to 22 days) required for larval development. An average of 17 days was required from egg. deposition to the pupal stage, divided as follows:

STAGE	PERIOD IN DAYS	
	Minimum	Maximum
Egg—(incubation)	5	8
Larva, 1st Stadium	2	4
Larva, 2nd Stadium	2	4
Larva, 3rd Stadium	4	6

SUMMARY.—Some of the ecological factors of the cherry fruit fly *Rhagoletis cingulata* (Loew) affecting egg development and deposition under various nutritional diets were investigated at the Irrigation Experiment Station, Prosser, Washington, in 1952 and 1953.

The general behaviour of the flies in the laboratory such as mating, flight, and other activities were similar to those in the orchard. Feeding punctures were found 2 to 3 days before the first egg. Eggs were deposited singly under the skin of the cherry. An average of 17 days was required from egg to pupae.

The optimum temperature for mating, egg development, egg production and egg deposition, was found to be 80° F. for each. The oviposition period varied from 1–36 days. It increased gradually with increase in temperature up to 90° F. At this temperature the period dropped suddenly to 1 day. The preoviposition period increased with each temperature decrease, and varied from 7 to 12 days.

Under the same diet, productivity decreased with each decrease in temperature. The supply of yeast increased fecundity and shortened the life span. Under a low light intensity of 10 foot-candles, the fecundity and life span were both increased.

In the preseason tests, using flies emerging from pupae kept at 32° to 40° F. for 5 months, eggs were deposited only by females kept at 80° F. The 70° F. temperature did not appear to retard egg development, while both 90° F. and 60° F. definitely did.

LITERATURE CITED

Caesar, L., and G. J. Spencer. 1915. Cherry fruit flies. Ont. Dept. Agr. Bul. **227**: 1–30.
Cox, J. A. 1952. The cherry fruit fly in Erie County. Penn. Agr. Expt. Bul. **548**: 1–17.
Frick, K. E. 1949. The present status of cherry fruit in the Yakima Valley. Wash. Hort. Assoc. Proc. **45**: 99–110.
Frick, K. E., Harold G. Simkover, and H. S. Telford. 1954. Bionomics of the cherry fruit flies in Eastern Washington. Wash. Agr. Expt. Sta. Tech. Bul. 13.
Illingworth, J. F. 1912. Cherry fruit flies and how to control them. Cornell Univ. Agr. Expt. Sta. Bul. **325**.
Uvarov, B. P. 1928. Insect nutrition and metabolism. Trans. Ent. Soc. London. **1928**: 255–343.

Equipment and Technique Used in Laboratory Evaluation of Pesticide Dusts in Toxicological Studies with Honeybees[1]

E. L. ATKINS, JR., L. D. ANDERSON, and T. O. TUFT, *University of California Citrus Experiment Station, Riverside*

This paper is presented in response to inquiries regarding details of the equipment and technique used in screening pesticide dust in toxicological studies with honeybees.

EQUIPMENT.—A bell-jar vacuum duster for use in insecticide tests has been described by Farrar *et al.* (1948). In Farrar's tests bean plants were dusted, and the insects were then confined with the plants, or the insects were dusted directly in hemispherical wire cages. Later, Richards & Murphy (1949) employed similar equipment for tests with fungicides on bean plants. Subsequently, McCallan (1950) made a thorough study of the various factors influencing deposition in the bell-jar vacuum duster. Bean plants were also used in these tests. Anderson & Tuft (1952) and Tuft & Anderson (1953) used the bell-jar vacuum duster for dusting *Lippia lanceolata* flowers, honeybees, and tomato plants in their studies.

The bell-jar vacuum duster used for evaluating pesticide dusts in honeybee toxicological studies at the Citrus Experiment Station (Atkins 1954) was built according to the general specifications of Farrar *et al.* (1948) and McCallan (1950), but with several modifications. During the testing, the equipment was placed adjacent to a large exhaust hood in a spray-dust laboratory, and a blast of air from an air hose was used to exhaust the bell jar and to remove dust from the stone base and watch-glass dust holder. This provided an efficacious method of removing excess dust from the equipment after each dusting operation. The bell jar, dust holder, and stone base were washed with hot water and dried after each test with a different pesticide.

FIG. 1.—Left, stock bee cage containing honeybees transferred from brood frames (observe top and bottom sections of cage, with handles and corked portholes). Right, aspirating apparatus containing dusting cage. This apparatus is used for transferring bees from stock cage to dusting cage.

The stock bee cage (Fig. 1) is constructed of soldered 8-mesh wire screening. The bottom section of the cage is 9 inches in diameter and 10 inches high, and

[1] Paper No. 815, University of California Citrus Experiment Station, Riverside, California.

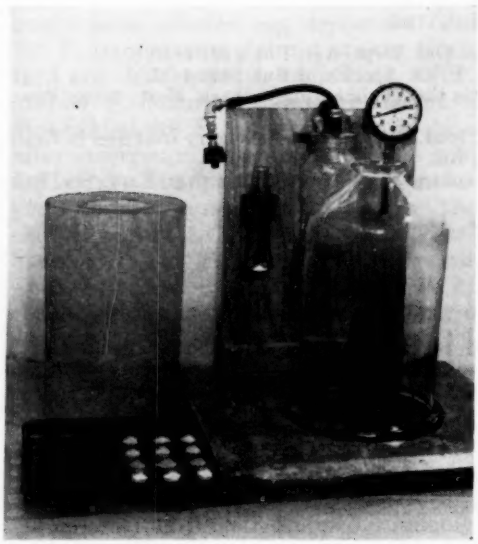


FIG. 2.—Bell jar with dusting cage inside, ready for assembly. The watch-glass dust holder is attached to the frame at the rear; safety screen and tray holding measured dosages of pesticides at left.

the cone-shaped top is 8 inches high. Both the top and the bottom sections of this cage are provided with handles. The top section has a $\frac{1}{2}$-inch aspirator port at its apex, and the bottom-section has two ports of the same size which are closed with corks. The test lots of honeybees are removed from the cage by an aspirator tube through these three ports. A 6×9-inch *Masonite* baffle is attached inside the cage base, leaving a $\frac{3}{8}$-inch space between the baffle and the bottom of the cage. The bees usually congregate on the baffle board or cluster in the top cone. The bees are generally aspirated off the baffle board through the side ports.

If it is necessary to hold honeybees in the stock cage for an indefinite length of time, they may be fed by setting the cage in a flat pan on paper toweling saturated with a honey-water or sugar-water solution. The stock cage is large enough to enable the bees to fly within it.

The aspirating apparatus (Fig. 1) used for transferring bees from the stock cage into the dusting cages is constructed of $\frac{1}{8}$ inch *Plexiglas*. The apparatus is $4\frac{1}{2}$ inches square and 7 inches high. A ⊥-shaped flange fixed on the top of the sides is $4\frac{3}{4}$ inches square and $\frac{1}{2}$ inch high. This flange receives the *Masonite* lid of the dusting cage. A $\frac{1}{4}$-inch vacuum nipple attached to one side of the apparatus is connected by tubing to a laboratory vacuum outlet which is provided with a regulating valve and turn cock. The lid is 5 inches square with $\frac{1}{2}$-inch sides, and has a hole $1\frac{1}{4}$ inches in diameter in the center for receiving the metal tube through which the aspirator tubing enters the top of the equipment. The aspirator tubing is secured tightly inside the metal tube with a cork bushing. A metal flange $\frac{1}{2}$ inch wide is soldered to the outside of the metal tube at the bottom. The aspirator tubing projects $\frac{1}{2}$ inch into the lid of the dusting cage. This tubing has an inside diameter of $\frac{5}{16}$ inch and is 30 inches long. The walls of the tubing must be thick enough to prevent collapse under the vacuum employed. The distal end of the tubing is provided with a glass tube 9 inches long and having a $\frac{9}{32}$-inch inside diameter. The size of the glass tube is critical, since it must be large enough to permit passage of the bees but small enough to prevent two or more bees from plugging the tube. A pliable plastic gasket is fitted inside the top of the aspirating apparatus between the lid and the metal flange of the metal tube. This gasket fits

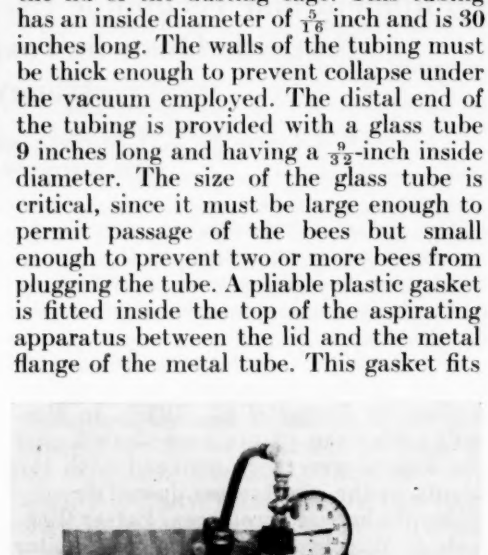


FIG. 3.—Bell-jar vacuum duster completely assembled.

snugly against the top of the ⊥-shaped flange and when the vacuum is applied, fits snugly against the lid of the dusting cage. Two rubber-band ring clamps are fixed to the apparatus to secure the lid.

The dusting cages (Figs. 2, 3, 4) are 3×6-inch cylinders closed at the bottom and constructed of soldered 18-mesh copper screening. The opening of the dusting cage is closed with a *Masonite* lid 4½ inches square and ⅛ inch thick. This lid contains a 1⅛-inch-diameter hole through which the bees are aspirated, and which is closed with a No. 15 cork. The lid is held in place by two 3-inch rubber bands looped together at one end to form a 6-inch band. The rubber band fits over the bottom of the cage and is fastened to the lid by looping the ends over two of the notched lid corners (Fig. 4).

Two types of funnels are used. The smaller one (Fig. 4), which is used to transfer the bees from the dusting cage into the holding cage, is constructed of celluloid. The top of the funnel is 4½ inches in diameter, and the sides are 5 inches in depth. The stem is 1 inch in diameter and 2 inches long. The larger funnel is used for transferring the bees from the hive frames to the stock cage. It is constructed of celluloid and is 18 inches in diameter at the top with a 3-inch opening at the bottom. The vertical height is approximately 14 inches. A 3-inch flange about 6 inches from the bottom on the outside of the funnel fits over the outside of the sides of the stock cage to steady the funnel and to prevent bees from escaping.

The holding cages (Figs. 4 & 5) are 5×5×5 inches in dimensions and are constructed of soldered 8-mesh wire screening. The lid contains a 1⅛ inch hole through which the treated honeybees are transferred. A No. 15 cork closes the hole in the lid. Each holding cage is identified by a numbered cork. Three-inch rubber bands are used to secure the lids. A metal spring clamp (of the type used to hold household cleaning-tool handles) is fixed in one corner of the bottom of the cage to secure the "feeder." The feeder is a 28×65-mm. glass shell vial which is stoppered with a plug of absorbent cotton to prevent the honey-water or sugar-water solution from escaping, and to allow the honeybees to feed.

TECHNIQUE.—The method of procedure followed when a typical series of toxicological tests are run is presented below. To utilize man-hours as efficiently as possible, three men are required. The test dusts, which have been previously prepared, are weighed on a balance. The samples are weighed directly onto individual watch-glasses, which are then systematically placed on trays (Fig. 2). Usually, a pesticide is tested in triplicate at each dosage level for each day's tests, and the tests are repeated on three different days.

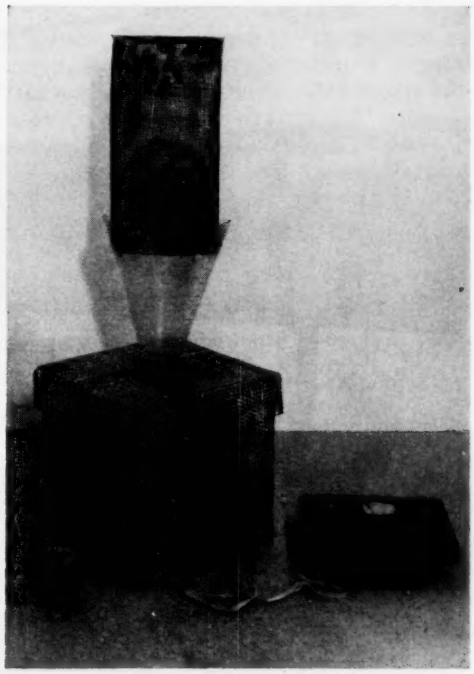


FIG. 4.—Dusting cage in position on small funnel for transfer of dusted honeybees to holding cage.

The feeders are filled with food, stoppered, and then placed in the spring clamps within the holding cages, the lids secured with rubber bands (Fig. 4). The small transferring funnel, the corks, and the assembled holding cages are taken into the dusting room. Next, the *Masonite* lids are placed on the dusting cages and held in place with rubber bands (Fig. 2). The bell-jar vacuum duster and air hose are taken to the dusting laboratory, and the hoses are fastened to the appropriate laboratory outlets. The stock cage, large funnel, and hive equipment are taken to the apiary. Frames of capped brood are removed from one of the hives, and the bees on these frames are shaken into a

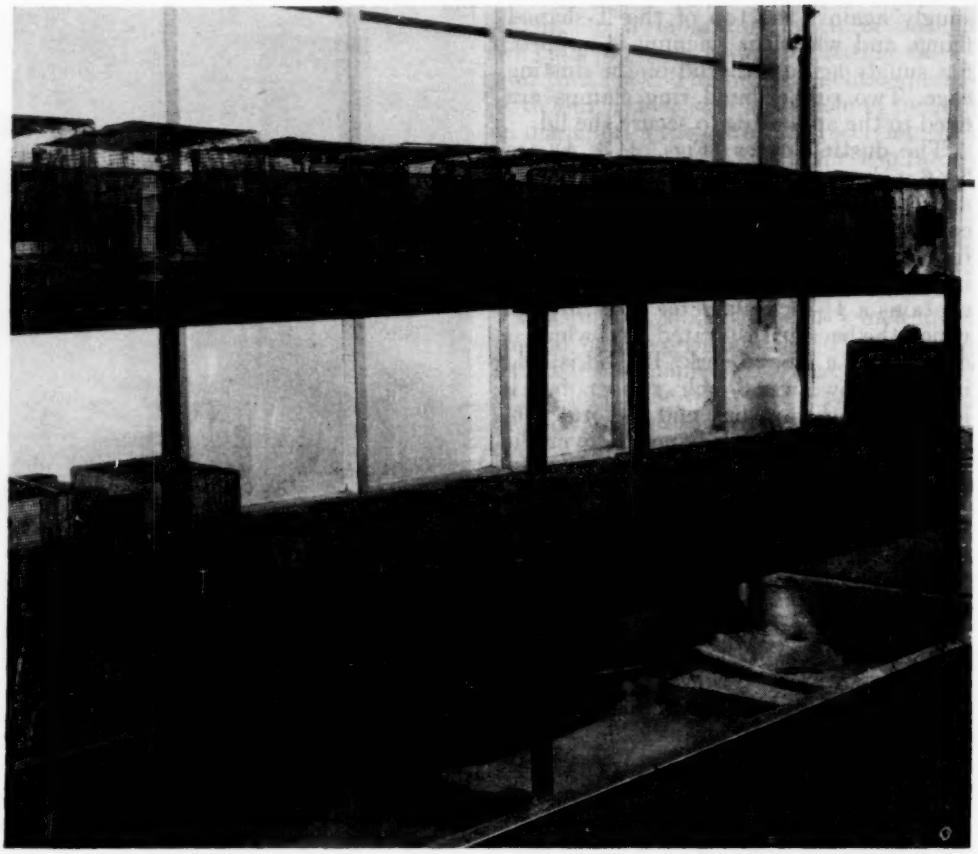


FIG. 5.—Holding cages of dusted honeybees on greenhouse shelves.

large funnel atop the bottom section of the stock cage. Generally, each frame has approximately 2500 bees on it, and most of these bees are approximately the same age. The funnel is then replaced with the conical top of the stock cage. The cage of bees is taken to the greenhouse room, where the bees are aspirated into the dusting cages.

At this time everything is in order to commence the actual dusting of the bees. An assembled dusting cage, minus cork, is placed in the aspirating apparatus (Fig. 2); 20 bees are transferred from the stock cage into it and the dusting cage is closed with a cork. The "loaded" cages are then placed on a tray and delivered to the dusting laboratory. While the dusting cages are being loaded, a cage of 20 bees (with the *Masonite* lid end downward) is placed in the bell-jar vacuum duster (Fig. 2); a watch-glass containing the dust sample is placed in the dust holder; the loaded unit is fitted into the top of the duster, and the vacuum line is turned on (Fig. 3). As soon as the desired vacuum is attained (19 to 23 p.s.i.), the vacuum valve is closed and the vacuum in the bell jar is released, dissipating the dust sample within the duster and dusting the bees. After a period of 15 seconds the dusted bees are removed and are transferred to the holding cage (Fig. 4), which is then transferred to the greenhouse (Fig. 5).

The procedure described above continues in uninterrupted sequence until the pesticide series is completed. Usually, 60 cages of bees constitute a series and these are normally dusted in 75 minutes.

After each test series the dusting cages and holding cages are washed in hot water containing trisodium phosphate and detergent; the cages are then rinsed with water, washed in benzene, allowed to air-dry, and, lastly, rinsed in acetone. All dusting-laboratory bench surfaces, trays, and so forth are covered with clean wrapping paper during each test. Extreme cau-

tion is practiced to prevent placing cages of bees on contaminated surfaces. The shelves in the greenhouse are likewise covered with clean paper for each test series. Separate containers are used for storing clean equipment and for contaminated or unwashed equipment. Under these conditions there has been no problem of contamination.

SUMMARY.—This paper presents photographs and descriptions of the bell-jar vacuum duster, holding cages, dusting cages, stock bee cages, aspirating apparatus, and other equipment used in the laboratory evaluation of pesticide dusts in toxicological studies with honeybees. The technique of utilizing this equipment in pesticide evaluation is given in detail, and the precautions employed to avoid contamination are disclosed.

LITERATURE CITED

Anderson, L. D., and T. O. Tuft. 1952. Toxicity of several new insecticides to honey bees. JOUR. ECON. ENT. **45**(3): 466–9.

Atkins, E. L., Jr., and L. D. Anderson. 1954. Toxicity of pesticide dusts to honeybees. JOUR. ECON. ENT. **47**(6): 969–72.

Farrar, M. D., W. C. O'Kane, and Howard W. Smith. 1948. Vacuum dusting of insects and plants. JOUR. ECON. ENT. **41**(4): 647–8.

McCallan, S. E. A. 1950. Factors influencing deposition in the vacuum bell jar duster. Boyce Thompson Inst. Contrib. **16**(1): 27–37.

Richards, M. C., and Douglas Murphy. 1949. The vacuum duster for applying fungicides and inoculum to plants. Phytopath. **39**: 20.

Tuft, T. O., and L. D. Anderson. 1953. Acaricides for control of tomato russet mite in California. JOUR. ECON. ENT. **46**(3): 502–4.

Toxicity of Pesticide Dusts to Honeybees[1]

E. L. ATKINS, JR., and L. D. ANDERSON,[2] *University of California Citrus Experiment Station, Riverside*

Because of the demand for further information concerning the effect of pesticides upon honeybees, *Apis mellifera* L., it seemed advisable to continue comparative toxicity studies. Results of tests of the relative toxicity to honeybees of 55 pesticide dusts, mostly insecticides, are reported in this paper.

MATERIALS AND METHODS.—The pesticides were tested in the laboratory under precisely controlled conditions of temperature, humidity, and time, using the vacuum bell-jar method of dusting developed by Farrar *et al.* (1948) and utilized in tests previously reported by Anderson & Tuft (1952). The equipment and technique employed in these screening tests are described in an accompanying paper (Atkins *et al.* 1954).

The pesticides evaluated are listed in tables 1, 2, and 3. Most of these dusts were prepared with pyrophyllite as the diluent. This eliminated much of the variation caused by the adverse effects that some diluents have on honeybees. A few materials were tested as unaltered commercial dusts. All the more toxic pesticides were tested at dosages of 100, 200, and 400 mg.; less toxic materials were tested at 400 mg. only. Each material was evaluated by dusting at least nine replicates of 20 bees each at each dosage level. A 200-mg. dosage of 5 per cent DDT dust was included in each series of tests as the standard treatment, in addition to untreated checks.

After the bees had been dusted they were transferred to clean holding cages provisioned with food consisting of a 50 per cent honey-water solution. The treated bees were held in a greenhouse room having a constant temperature of 80° F. and a relative humidity of 65 per cent. A hygrothermograph record was obtained for each test series. Observations and mortality counts were subsequently made at appropriate time intervals.

RESULTS.—The results obtained in

[1] Presented at the First Annual Meeting of the Entomological Society of America at Los Angeles, California, December 7–10, 1953. Paper No. 814, University of California Citrus Experiment Station, Riverside.

[2] The authors acknowledge the valuable assistance of H. T. Reynolds, P. D. Gerhardt, M. H. Frost, G. E. Printy, R. M. Hannibal, and Richard Smith in the laboratory phase of the testing.

Table 1.—Comparative toxicity of pesticide dusts to honeybees at *400-mg. dosages.*

Pesticide[1]	Per Cent	Per Cent Mortality (Hours After Treatment) 2	4	6	12	24	48	72
DNOSOBP[2]	10	91	97	100	—	—	—	—
Sabadilla	20	11	51	85	99	100	—	—
Aldrin	2	2	18	35	99	100	—	—
Lindane	1.5	—	60	76	97	100	—	—
Methyl parathion	2	58	67	71	84	100	—	—
Metacide	2	76	76	76	76	100	—	—
Parathion	2	21	39	66	72	100	—	—
Malathion	2	16	23	30	50	100	—	—
EPN	2	60	60	75	96	99	100	—
Endrin	2	0	14	71	96	99	100	—
BHC	2	1	30	50	95	99	100	—
Dieldrin	2	1	19	38	90	99	100	—
Chlordane	5	0	1	18	82	99	100	—
Diazinon[3]	5	0	24	47	71	99	100	—
TEPP	1	36	36	38	40	98	100	—
Heptachlor	2	0	15	49	82	94	100	—
Calcium Arsenate	70	2	3	17	54	79	94	100
Q-137	5	0	19	58	83	93	94	95
Isodrin	2	0	0	11	37	72	94	95
DDT	5	1	31	46	73	91	91	91
Compound 1189[4]	5	0	0	1	1	4	54	79
NPD[5]	4	1	24	59	69	71	71	72
Tartar emetic	99	0	7	12	29	41	48	53
Chlorobenzilate[6]	4	0	0	10	34	45	48	50
Cryolite	50	0	0	6	20	28	34	37
Methoxychlor	5	0	6	7	12	36	36	36
Compound 876[7]	10	0	1	2	3	3	7	34
Ryania	40	0	0	4	21	28	30	31
Toxaphene	10	0	0	1	6	8	26	30
CMU[8]	10	0	0	1	3	5	26	30
CS-708	5	0	2	6	17	22	26	26
R-242	10	0	2	4	10	23	25	26
Compound Q-128[9]	5	0	5	5	6	16	21	24
Sulfur	98	0	0	1	2	8	19	24
Aramite	3	0	0	0	4	15	19	21
TDE (DDD)	5	3	5	6	9	16	17	20
DNOCHP[10]	10	—	2	4	10	12	13	17
Rotenone	1	0	0	1	6	8	12	16
Ovotran	7.5	0	0	0	9	12	15	15
Chlorinated terpine	5	0	2	3	7	8	12	14
Pyrethrins	0.26	1	2	4	6	8	11	13
Demeton	1	0	0	0	2	5	10	13
Compound 923	10	0	3	4	4	4	9	13
Neotran	7.5	1	2	3	4	6	9	11
Checks	—	0	0	1	2	4	7	9
Allethrin	0.26	1	1	1	2	4	6	9
DMC	10	0	0	0	2	3	5	7
Cunilate[11]	5	1	2	3	4	4	5	5
Nicotine	3.6	1	1	1	2	3	3	3

[1] Definitions of most of the pesticides not footnoted below may be found in the "Report of Committee on Insecticide Terminology," Jour. Econ. Ent. **45**(1): 165–6.
[2] DNOSOBP is 2,4-dinitro-*o*-sec-butyl phenol (DN-211).
[3] Diazinon is 0,0-diethyl-0 (2-isopropyl-4-methyl Pyrimedyl (6) thiophosphate).
[4] Compound 1189 is 2,3,3a,4,5,6,7,8,8-dichloro-3a,4,7,7a-tetrahydro-4,7-methanoindine-1-one.
[5] NPD is tetra-*n*-propyl dithionopyrophosphate.
[6] *Chlorobenzilate* is 4,4-dichlorobenzilic acid ethyl ester (Geigy 338).
[7] Compound 876 is bis(*p*-chlorophenyl) ethynyl carbinol.
[8] CMU is 3-(*p*-chlorophenyl)-1,1-dimethyl urea.
[9] Q-128 is the ethyl analogue of DDT; 1,1-trichloro-2,2-bis-(*p*-ethylphenyl)ethane.
[10] DNOCHP is 4,6-dinitro-*ortho*-cyclohexylphenol (DN-111).
[11] *Cunilate* is copper 8-hydroxyquinolinate.

these tests are presented in tables 1, 2, and 3. The DDT standard treatment and the untreated checks are set off by line guides for purposes of comparison.

In these experiments DNOSOBP[3] was the most toxic chemical tested, as it gave complete mortality in about half the time required for the next most toxic material. DNOSOBP and sabadilla affected bees similarly in that each caused an early permanent paralysis followed by death. Bees treated with EPN exhibited unusual behavior in that after the initial early paralysis, mortality proceeded most rapidly in reverse proportion to the dosage level. This phenomenon may have been due to the regurgitative effect that the organophosphates had on the bees. EPN, methyl parathion, Metacide, parathion, TEPP, malathion and Diazinon caused the bees to regurgitate violently. This effect was most pronounced with the 400-

[3] See tables for definitions of pesticides used in these tests.

Table 2.—Comparative toxicity of pesticide dusts to honeybees at *200-mg. dosages.*

Pesticide[1]	Per Cent	Per Cent Mortality (Hours After Treatment) 2	4	6	12	24	48	72
DNOSOBP	10	91	97	100	—	—	—	—
EPN	2	31	48	86	99	100	—	—
Sabadilla	20	3	37	80	97	100	—	—
Lindane	1.5	0	0	49	96	100	—	—
BHC	2	0	0	52	93	100	—	—
Heptachlor	2	0	7	46	92	100	—	—
Compound 22/190[2]	5	16	55	64	88	100	—	—
Metacide	2	70	72	72	86	100	—	—
Aldrin	2	1	15	32	81	100	—	—
Dieldrin	2	0	0	26	81	100	—	—
Diazinon	5	19	31	54	74	100	—	—
Malathion	2	17	21	26	54	100	—	—
Methyl parathion	2	46	70	90	94	99	100	—
Parathion	2	26	50	66	73	98	100	—
TEPP	1	37	37	37	45	96	100	—
Compound A-42[3]	5	1	12	34	55	73	94	96
Compound 340[4]	1	3	46	75	87	93	95	95
Endrin	2	0	7	61	86	87	92	92
Chlordane	5	0	1	2	16	46	67	92
Potasan[5]	2	1	4	34	79	81	83	84
Compound 21/116[6]	2	0	22	36	60	68	73	75
Q-137	5	0	8	46	63	72	72	72
DDT	5	1	11	25	44	61	65	65
Calcium arsenate	70	0	2	3	6	18	45	63
Isodrin	2	1	1	1	11	28	56	62
Compound 1189	5	0	1	1	1	4	36	62
Compound 21/199[7]	5	0	1	10	22	27	39	44
NPD	4	0	2	14	25	27	28	30
TDE (DDD)	5	2	3	4	6	15	18	28
Schradan	2	0	1	6	15	21	23	26
Methoxychlor	5	0	1	2	3	23	24	24
DNOCHP	10	0	3	5	18	20	21	23
Toxaphene	10	0	1	3	4	9	18	21
Sulfur	98	0	0	1	1	1	10	17
Rotenone	1	0	0	1	6	8	12	16
Compound Q-128	5	0	0	0	0	11	12	13
Demeton	2	0	1	2	4	5	8	9
Check	—	0	0	1	2	4	7	9
CS-708	5	0	0	0	2	2	3	4

[1] Definitions of most of the pesticides not footnoted below or in table 1 may be found in the "Report of Committee on Insecticide Terminology," Jour. Econ. Ent. **45**(1): 165–6.
[2] *Chlorthion* is 0,3-chloro-4-nitrophenyl 0,0-dimethyl thiophosphate.
[3] Compound A-42 is arsenomethane As-1,2-disulphide.
[4] Compound 340 is 1-isopropyl-3-methyl-pyrazolyl-(5)-dimethyl carbamate (Isolan).
[5] Potasan is dithoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin.
[6] Compound 21/116 is 0,0-dimethyl 0-ethyl-2-thioethyl ethyl thionophosphate.
[7] Compound 21/199 is 0,0-diethyl-0-(3-chloro-4-methyl-4-hydro-7-hydroxy coumarin).

mg. dosage, slightly less with the 200-mg. dosage and only slightly or not at all with the 100-mg. dosage. With EPN, it seems possible that violent regurgitation delayed the absorption of a lethal amount of the chemical. In addition, the above-named phosphates caused a complete paralysis of the bees within 15 minutes after treatment. Subsequently, the bees regained some spasmodic movement, particularly of the stinger, wings, antennae, and legs, and especially of the tarsi; but in no instance did any bee regain normal movements.

Nicotine caused partial paralysis within a few minutes after treatment, followed by complete recovery within approximately 30 minutes. DDT and most of the more toxic chlorinated hydrocarbons effected almost all of their mortality within the first 24 hours. Calcium arsenate and compounds 1189, 923, and 876 apparently exhibited a substantial amount of toxicity as stomach poisons, for most of the mortality caused by these materials was delayed 24 to 48 hours. Dusted honeybees not seriously affected by a pesticide began cleaning themselves immediately after transfer into the holding cages. Some insecticides may reach the gut by this method.

Results of previous work by Anderson & Tuft (1952) showed several apparent differences from the results presented here. Anderson and Tuft considered the more or less complete paralytic moribundity of the bees as mortality. However, in the present series of tests, a bee was considered dead only after no movement had been observed for several seconds. Particularly with the organophosphates, it was necessary to observe the apparently dead bees for several subsequent time intervals to be certain that there was no recovery from complete paralysis.

In the previously reported series of tests (Anderson & Tuft 1952), the treated bees were held in the greenhouse under normal greenhouse temperature and humidity, the average temperature being considerably higher than the 80° F. used in this present series of tests and the humidity substantially below 65 per cent. Exploratory studies on temperature and humidity indicate that a high temperature (90° F.) and a low humidity (30 per cent) will substantially increase the mortality interval.

Table 3.—Comparative toxicity of pesticide dusts to honeybees at *100-mg. dosages*.

Pesticide[1]	Per Cent	Per Cent Mortality (Hours After Treatment) 2	4	6	12	24	48	72
EPN	2	8	54	94	100	—	—	—
Lindane	1.5	0	0	38	95	100	—	—
Metacide	2	65	67	69	84	100	—	—
Methyl parathion	2	2	3	48	84	100	—	—
Parathion	2	22	44	57	73	100	—	—
Dieldrin	2	0	0	15	67	100	—	—
BHC	2	0	0	44	98	99	100	—
Diazinon	5	0	6	36	62	98	100	—
Heptachlor	2	0	0	9	71	96	100	—
TEPP	1	28	28	29	47	95	100	—
Aldrin	2	0	12	24	59	99	99	100
Malathion	2	15	20	25	52	99	99	99
Chlordane	5	1	2	3	12	28	50	75
Endrin	2	0	1	31	54	56	61	63
Isodrin	2	1	1	1	7	20	49	54
Compound 1189	5	0	0	0	2	17	34	48
DDT	5	0	1	9	21	44	46	47
Heptachlor	0.5	0	1	2	4	13	36	46
Calcium arsenate	70	0	1	2	5	10	20	28
Compound Q-128	5	3	5	8	16	17	19	23
Q-137	5	0	0	12	16	21	22	22
CMU	10	0	1	1	1	3	11	17
Methoxychlor	5	0	3	4	6	14	15	15
Sulfur	98	0	0	1	2	5	12	13
NPD	4	0	1	6	8	9	9	13
Demeton	1	0	3	3	4	4	9	11
TDE (DDD)	5	0	0	0	0	4	6	11
Checks	—	0	0	1	2	4	7	9
DNOCHP	10	0	3	3	4	6	8	8
Toxaphene	10	0	0	0	2	3	5	7
CS-708	5	0	1	2	4	4	4	4

[1] Definitions of the pesticides listed may be found in footnotes of tables 1 or 2 or in the "Report of Committee on Insecticide Terminology," JOUR. ECON. ENT. **45**(1): 165–6.

In the Anderson & Tuft (1952) tests, honeybees were obtained from various apiaries in lots of 1 or 2 pounds and were held for as long as a week in stock cages provided with food. The test lots of bees were then removed as needed. In the series of tests reported herein, bees of uniform age were obtained from the newly established departmental apiary just prior to dusting.

The factors discussed above serve to demonstrate a few of the refinements adopted in the recent studies to alleviate some of the variables that are prevalent in this type of biological research.

DISCUSSION.—Field experience has demonstrated that DDT can be used safely when applied while the foraging bees are not actively working a field. It is therefore assumed that pesticides which are less toxic than DDT in these laboratory tests may usually be utilized safely under commercial conditions, and that pesticides which are more toxic than DDT in the laboratory tests may generally be assumed to be too toxic for commercial usuage where bees are present, unless special application techniques of proper

timing, dosage, and method of application can be employed.

It should be noted that the present tests evaluate primarily the contact effect of the various materials. It should be noted, also, that materials like calcium arsenate are known to be fairly strong stomach poisons to honeybees.

In the field arsenicals have caused serious losses to apiaries. There may be materials other than arsenicals that are less toxic to bees than DDT as a contact poison but more toxic as a stomach poison; thus both methods of toxicity must be considered before a chemical can be positively identified as safe.

Another factor to be considered in the use of pesticides that appear to be more toxic than DDT is that sometimes such small amounts of the chemical are required to control the insect pest that a bee toxicity hazard does not exist. This may be true with sabadilla used for thrip control on citrus. Another important factor that must be considered when making comparisons is the length of residual action of a given pesticide. For example, TEPP is highly toxic to bees, but it dissipates very rapidly and thus kills only bees contacted at the time of application.

Still another factor that has arisen with the new systemic chemicals is translocation of the poison to the nectaries and pollen of the plants treated. In this manner the chemical is made available to the bees to feed on and store in their hives. Schradan, for example, has been shown by Jones & Thomas (1953a, 1953b), in England, to appear in the nectaries of mustard and borage flowers for 4 weeks after treatment, and has been transferred by bees to honey in the hive. The highest concentration found was 21 p.p.m.; however, most of the results gave much lower concentrations. Schradan was found to be stable in the bee stomach; it was also stable in honey for 2½ months after treatment.

SUMMARY.—Results of laboratory tests evaluating the relative toxicity of 55 pesticides to honeybees are reported. Each chemical was prepared as a dust, using pyrophyllite as the diluent. All materials were applied with a bell-jar vacuum-duster. Each pesticide test was replicated nine or more times, and in each series of tests a dosage of 5 per cent DDT dust was used as the standard treatment, in addition to untreated checks.

Materials highly toxic to honeybees were the following: DNOSOBP, EPN, sabadilla, lindane, BHC, heptachlor, *Chlorthion*, Metacide, aldrin, dieldrin, Diazinon, malathion, methyl parathion, parathion, TEPP, compound A-42, compound 340, endrin, and chlordane. Moderately toxic materials were: Potasan, compound 21/116, Q-137, DDT, calcium arsenate, isodrin, compound 1189, tartar emetic, *Chlorobenzilate*, compound 21/199, cryolite, compound 876, ryania, NPD, TDE, R-242, schradan, methoxychlor, DNOCHP, Aramite, and toxaphene. Relatively safe materials were: sulfur, rotenone, *Ovotran*, chlorinated terpine, compound Q-128, pyrethrins, compound 923, *Neotran*, CMU, demeton, allethrin, DMC, *Cunilate*, CS-708 and nicotine.

LITERATURE CITED

Anderson, L. D., and T. O. Tuft. 1952. Toxicity of several new insecticides to honeybees. JOUR. ECON. ENT. **45**(3): 466–9.

Atkins, E. L., Jr., L. D. Anderson, and T. O. Tuft. 1954. Equipment and technique used in laboratory evaluation of pesticide dusts in toxicological studies with honeybees. JOUR. ECON. ENT. **47**(6): 965–9.

Farrar, M. D., W. C. O'Kane, and Howard W. Smith. 1948. Vacuum dusting of insects and plants. JOUR. ECON. ENT. **41**(4): 647–8.

Jones, G. D. G., and W. D. E. Thomas. 1953a. Contamination of nectar with the systemic insecticide "Schradan." Nature **171**(4345): 263

Jones, G. D. G., and W. D. E. Thomas. 1953b. Experiments on the possible contamination of honey with Schradan. Ann. Appl. Biol. **40**(3): 546–55.

Distribution of Radioactive Phosphorus in Susceptible and Resistant House Flies

FRANK H. BABERS and C. C. ROAN,[1] *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Radioactive phosphorus (P^{32}) mixed in the food of various stages of the greater wax moth, *Galleria mellonella* (L.), German cockroach, *Blattella germanica* (L.), yellow mealworm, *Tenebrio molitor* L., and firebrat, *Thermobia domestica* (Pack.), soon appeared in the insects as phospholipids, phosphoproteins, hexosephosphates, phosphoglyceric acid, and adenyl triphosphoric acid (Lindsay & Craig 1942). Grosch & Sullivan (1952, 1953) fed P^{32} to females of *Habrobracon juglandis* (Ashm.) (=*Bracon hebetor* (Say)) and studied its distribution and its effect on egg production and viability. The deposition of P^{32} in developing *Drosophila melanogaster* Meig. was investigated by Irwin *et al.* (1950). Using microanalytical chemical procedures, Levenbook (1953) studied the variation of numerous phosphorus compounds during the metamorphosis of the blow fly *Calliphora erythrocephala* Meig. (=*C. vicina* R. D.). Lu & Bodine (1953) made a similar study on developing eggs of the differential grasshopper, *Melanoplus differentialis* (Thos.).

None of these workers used insects that had become resistant to insecticides. That physiological differences exist between susceptible and resistant species has been established, but the physiological role of these differences and the causes of resistance are not yet clear (Chadwick 1952).

Because high-level reistance to the organic phosphorus insecticides has not yet developed in the house fly, *Musca domestica* L., either from field or laboratory exposure, Entomology Research Branch has been interested in the enzyme systems involved in the metabolism of these compounds as well as the general phosphorus requirements of the insect. This paper reports the results of experiments to determine whether any gross differences exist in the distribution of phosphorus between a susceptible and resistant strain of house flies.

MATERIALS AND METHODS.—The strains of house flies compared were the susceptible S-F, derived from NAIDM 1948 stock, and the resistant R-OB, selected for DDT resistance for 143 generations.

To about 300 ml. of standard NAIDM medium (Anonymous 1951) was added 1 ml. of potassium acid phosphate-P^{32} solution,[2] which had a specific radio-activity of 4.2×10^6 counts per minute per milliliter and contained 8 micrograms of phosphorus per milliliter. This corresponded to about 0.137 millicurie of P^{32} per milliliter. Fly eggs were added, and the culture was maintained in a room held at $26\pm2°$ C. and 50 ± 5 per cent relative humidity. The resulting adults were fed a 1:2 mixture of sucrose and powdered whole milk, with water given separately.

The acid-soluble phosphorus in the insects was determined after groups of 5 had been ground with ice-cold 10 per cent trichloroacetic acid, 1 ml. per insect. After centrifugation in the cold, the residue was washed with an equal portion of ice-cold trichloroacetic acid, and the supernatants were combined and evaporated to dryness in a large test tube placed about 1 inch above an electric hot plate. Then 1 ml. of 10 *N* sulfuric acid was added, the digestion continued until heavy charring, 1 drop of 30 per cent hydrogen peroxide added, and the digestion continued. The peroxide addition followed by heating was repeated until the solution was clear. After cooling and dilution of this extract to 10 ml., radioactivity counts were made and the total phosphorus was determined colorimetrically with Fiske and SubbaRows' reagent (Hawk *et al.* 1947). The readings were made at a wave length of 820 millimicrons.

The residue from the trichloroacetic acid fraction was extracted with small quantities of hot absolute ethyl alcohol, 30°–60° C. petroleum ether, and ethyl ether, and diluted to 25 ml. A portion of this extract was used for radioactivity counts. An aliquot was then evaporated and the total phosphorus of this lipoid fraction determined as before.

The residue from the lipoid extraction was digested and the radioactive and total phosphorus determined as before.

[1] Present address Department of Entomology, Kansas State College, Manhattan, Kansas.

[2] Prepared by dilution of material obtained from the Oak Ridge National Laboratory.

Table 1.—Distribution of radioactive phosphorus in extracts of house flies reared on medium containing P^{32}. Counts per minute per insect.

Stage of Insect	Trichloroacetic Acid Fraction		Lipoid Fraction		Residue		Total[1]	
	S-F	R-OB	S-F	R-OB	S-F	R-OB	S-F	R-OB
Freshly pupated	1055±40	1015± 39	308±22	300±63	305±15	439±15	1858±115	1867± 60
Adults less than 12 hours old:								
Males	858±14	775± 77	384±34	234±18	381±49	300±56	1625±435	1400±160
Females	846±62	940±201	300±54	288±22	356±23	338±91	1400± 85	1725±140
Adults 5 days old:								
Males	253±18	403± 9	222±18	241±50	138±23	125±13	625± 70	825±125
Females	388±60	492± 29	256±46	225±12	225±16	213±24	1000±160	925±125

[1] Results of independent analyses.

The analyses were run in duplicate with two replications. The counts were made on samples prepared in aluminum counting cups about 0.6 cm. from the 1.4 mg./cm.^{2} window of a G-M tube. Counts were adjusted for background and decay, 14.3 days being used as the half life of P^{32}. Generally the samples were counted long enough so that the error was about 1 per cent. Therefore the standard deviations shown reflect almost entirely the biological variation. Counts were also made on intact insects of various ages.

RESULTS.—The results of the radiological analyses of the several fly extracts are shown in table 1.

Small intact larvae 24 hours after hatching had an activity of 190 counts per minute per insect. Third-instar larvae actively feeding averaged about 900 counts per minute per insect. Counts on 30 whole pupae ranged from 1728 to 3456, with an average of 2820 for S-F and 2496 for R-OB, but this difference was not significant. Eggs from adults that had an activity of about 1000 counts per minute were placed in regular non-radioactive medium and the resulting larvae reared to adults. These adults had an activity of 11 counts per minute. Thus some of the radioactive phosphorus that was ingested by the parent insects while in the larval stage was transmitted to the progeny.

The results of the analyses for total phosphorus in the various fractions are shown in table 2. The only significant difference between the strains was that shown by the 5-day-old females. It may

Table 2.—Distribution of total phosphorus in extracts of house flies reared on medium containing P^{32}. Micrograms per insect.

Stage of Insect	Trichloroacetic Acid Fraction		Lipoid Fraction		Residue		Total[1]	
	S-F	R-OB	S-F	R-OB	S-F	R-OB	S-F	R-OB
Freshly pupated	27.6	27.5	10.0	10.8	17.8	18.1	49.2	46.8
Adults less than 12 hours old:								
Males	19.7	14.5	8.7	5.2	10.1	6.9	35.8	30.5
Females	23.2	22.0	9.4	8.3	10.5	10.5	37.3	38.9
Adults 5 days old:								
Males	19.7	19.3	10.4	10.7	4.2	5.2	31.2	31.5
Females	36.0	31.8	17.2	11.5	16.3	9.1	67.4	48.5

[1] Results of independent analyses.

Table 3.—Distribution of phosphorus in medium on which house flies were reared.

Fraction	Radioactivity, Counts per Minute per Milligram Dry Weight		Total Phosphorus, Micrograms per Milligram	
	S-F	R-OB	S-F	R-OB
Trichloroacetic acid	372	451	11.3	16.3
Lipoid	30	39	0.7	0.8
Residue	66	52	1.9	1.3
Total[1]	519	488	16.3	15.8

[1] Results of independent analyses.

have been due to their oviposition habits, as the resistant insects neither were so prolific nor produced over so long a period as the susceptible ones.

In each series of tests the ratio of radioactive to total phosphorus increased from 5-day females to 5-day males to 12-hour females to 12-hour males. No radioactive phosphorus was ingested after pupation, but the total phosphorus increased in the adults, since large amounts were present in the food.

After pupation the rearing medium was analyzed for phosphorus, with the results shown in table 3. Of the total phosphorus present only about 0.004 per cent was radioactive, all of which was inorganic.

CONCLUSION.—As a result of these experiments it is clear that house fly larvae are able to utilize inorganic phosphorus to synthesize phosphates of widely differing chemical nature. The radioactive phosphorus decreased rapidly in the adult insects except in the lipoid fraction. The biological half life of the radioactive material was 4.7 days for the trichloroacetic acid fraction, 5.3 days for the residue, but more than 11 days for the lipoid fraction. This work emphasizes the necessity for supplementing radioisotopic techniques with routine chemical procedures in the study of biological processes.

LITERATURE CITED

Anonymous. 1951. Peet-Grady method. Soap and Sanit. Chem. 1951 Blue Book and Cat. Ed., pp 237–43.

Chadwick, L. E. 1952. The current status of physiological studies on DDT resistance. Amer. Jour. Trop. Med. and Hyg. 1: 404–11.

Grosch, D. S., and R. L. Sullivan. 1952. The effect of ingested radiophosphorus on egg production and embryo survival in the wasp *Habrobracon*. Biol. Bul. **102**: 128–40.

Grosch, D. S., and R. L. Sullivan. 1953. The fate of radiophosphorus ingested by *Habrobracon* females. Biol. Bul. **105**: 296–307.

Hawk, P. B., B. L. Oser, and W. H. Summerson. 1947. Practical physiological chemistry. Ed. 12, 1323 illus. Philadelphia.

Irwin, R. L. B., J. W. T. Spinks, and T. J. Arnason. 1950. Deposition of P^{32} in developing *Drosophila*. Canad. Jour. Res. Sect. D, Zool. Sci. **28**: 137–42.

Levenbook, L. 1953. The variation in phosphorus compounds during metamorphosis of the blow-fly *Calliphora erythrocephala* Meig. Jour. Cell. and Compar. Physiol. **41**: 313–33.

Lindsay, E., and R. Craig. 1942. The distribution of radiophosphorus in wax moth, mealworm, cockroach, and firebrat. Ent. Soc. Amer. Ann. **35**: 50–6.

Lu, K. H., and J. H. Bodine. 1953. Changes in the distribution of phosphorus in the developing grasshopper (*Melanoplus differentialis*) embryo. Physiol. Zool. **26**: 242–54.

Laboratory Studies on Factors Influencing the Efficiency of Insecticide Impregnated Cords for House Fly Control[1]

R. W. FAY and DONALD A. LINDQUIST

In many areas, resistance in the house fly, *Musca domestica* L., has nullified control by the use of residual deposits of DDT and most other halogenated-hydrocarbon insecticides. Certain other insecticides, while still effective against resistant flies, are either too toxic for residual spray applications or show only limited residual action. These compounds have required new methods of use, one being the insecticide impregnation of cords which are suspended in the upper portions of fly infested structures. In these applications the treated cords represent only a small portion of the resting surface available to flies. Since the killing efficiency of the insecticide-impregnated cords is dependent upon contact with the flies, factors which influence the attractiveness of the cords to flies are important.

This paper presents laboratory studies of certain attraction factors such as cord material, size, color, and the inclusion of chemical attractants. Laboratory evaluations of the effectiveness of various insecticide-treated cords are also discussed.

MATERIALS AND METHODS.—The cylindrical test cage (Figure 1) consisted of two end rings (6″ outside diameter, 5″ in-

[1] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Georgia.

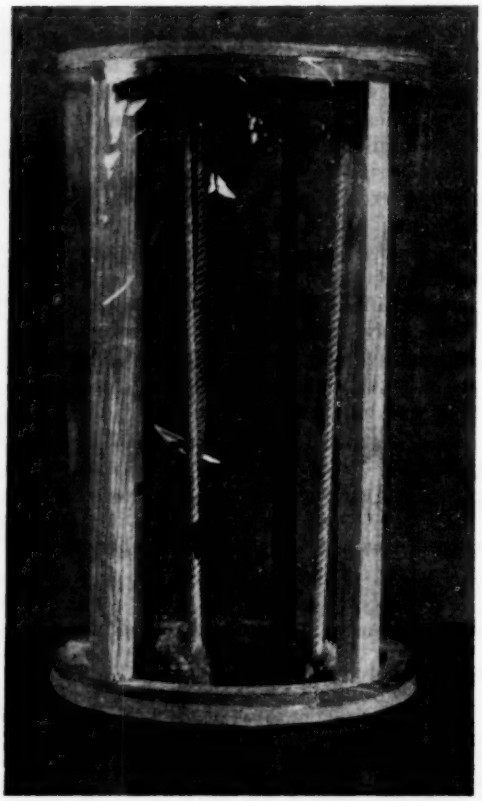


FIG. 1.—Cylindrical test cage for evaluation of cords showing flies under test.

side diameter) of $\frac{1}{2}''$ plywood supported by four equally spaced wooden posts, $\frac{1}{2}'' \times \frac{1}{2}'' \times 9''$. Cellophane, taped to the end rings and glued to each post, formed the sides of the cage. Each end support for test cords was made from three 6″ lengths of $\frac{3}{32}''$ diameter brass rod bent to a 60° angle at their centers and soldered together to form a six-spoked support. The cage ends were covered with 16-mesh wire-screen discs held in place with masking tape.

The test cord, in 10″ lengths, was bound on the ends with corsage wire to prevent unraveling and to provide a means of attachment. It was treated as required for the specific tests. In testing, the cords were stretched tautly between parallel spokes of the end supports. With one wire-screen end disc in place, the cage was ready for the test insects.

Using 3-day-old adults of a DDT-dieldrin resistant strain of house flies, groups of 50 females under CO_2 anesthesia were placed in individual cardboard cartons having wire-screen ends. After all insects for a given series were selected, they were reanesthetized lightly and placed rapidly into test cages. The second end disc of each cage was then fastened securely.

Flies on the test cords were counted at regular intervals during a test period. With insecticide-treated cords, additional counts of knocked-down flies were made. Between counts the cages were jarred sharply to disturb the flies. When 24-hour mortalities were required, the flies were anesthetized at the end of the exposure period and transferred to holding cages.

In the cage design, the following factors were considered: (1) The insects were given a choice of wire screen, metal rod, wood, cellophane, and cord as resting surfaces; (2) the cage was constructed to provide fairly uniform light intensities which permitted accurate observations and minimized any light attraction; (3) the ends were covered with wire screen to minimize any fumigant action of insecticides; and (4) the design allowed one, two, three, or six types of cord to be tested.

RESULTS.—To determine the attractiveness of various basic fibers to flies, $\frac{3}{32}''$ diameter cords of cotton, jute, wool, and sisal were each tested alone, using six lengths of cord placed vertically in a test cage. Ten counts at 10-minute intervals were made on each of three groups of 50 flies. In these individual tests cotton cord attracted an average of 5.3 flies, jute cord 3.4 flies, wool cord 0.8 flies, and sisal cord 5 flies. Comparisons were then made between cotton cord and each of the other types using three lengths of each type mounted alternately in a test cage. The ratios of flies on the competing cords were cotton:jute, 4.5:2.1, cotton:wool, 2.3:0.8, and cotton:sisal, 6.2:8.1. Although the sisal cord appeared slightly more attractive than cotton cord, the latter was selected for further testing since it was avilable locally in a wider variety of sizes and types and also appeared more suitable for treatment with dyes and insecticides.

The attractiveness value of cord size was investigated using seven cotton cords ranging in diameter from $\frac{3}{64}''$ to $\frac{7}{16}''$. Each size was tested alone using six lengths of cord per cage and observations on 50 female house flies on 4 different days. Flies on the cords were counted at 6-minute intervals for 1 hour comparing the cords in horizontal and vertical test positions. Three cord sizes were more attractive

Table 1.—Average number of 50 adult female house flies resting on 5 linear feet of different size cotton cords tested alone and in competition with a standard 3/32″ cotton cord.

Cord Diameter (Inches)	Cord Structure	Average Number of Flies on Cords[1]			
		Tested Alone	Versus 3/32″ Cord		Relative Attractiveness
			Test Cord	3/32″ Cord[2]	
7/16	corded 3 strand 120 yarns	9.6/[3] / 8.3	10.2/ /11.0	3.2/ /3.4	9.8
1/4	smooth 1 strand 40 yarns	7.8/ / 7.0	8.6/ / 7.6	3.0/ /3.0	7.8
3/16	corded 3 strand 93 yarns	10.5/ /10.3	7.2/ / 7.6	3.2/ /3.4	8.9
1/8	smooth 1 strand 31 yarns	4.9/ / 5.7	— —	— —	—
3/32	smooth 1 strand 20 yarns	6.5/ / 6.3	— —	— —	—
1/16	corded 3 strands 18 yarns	5.9/ / 6.4	3.8/ / 3.4	3.6/ /3.6	4.9
3/64	corded 3 strands 9 yarns	2.7/ / 3.1	— —	— —	

[1] Results are averages of 40 observations.
[2] Adopted as standard from tests with cords of various fibers.
[3] Upper figure represents cage in horizontal position. Lower figure represents cage in vertical position.

than the $\frac{3}{32}''$ diameter cord selected as the standard (Table 1). These, in competition with the standard cord, were studied further. The relative attractiveness value of each size cord was obtained by averaging the individual and competitive tests.

In general, attractiveness increased with the cord diameter and little difference occurred between the horizontal and vertical cords. The $\frac{3}{16}''$ diameter cord was selected for all further work on the basis of price and ease of handling.

Cords dyed Jungle Green, American Beauty Red, Brilliant Yellow, Powder Blue, and Black[2] were compared for their relative attractiveness to flies. Using 5 gms. of dye in 200 ml. of hot water containing 0.5 ml. of *Triton X-100*[3], cords were immersed for 10 minutes and then dried. The numbers of flies resting on 5 linear feet of each color cord tested, (a) alone and (b) in competition with white cord, were averaged to obtain a relative attractiveness index for each color (Table 2). Tests of each color separately and with white cord showed red and black to be the preferred colors.

Limited tests were made to increase the attractiveness of cords to house flies by dipping the cords in solutions of butyl alcohol, butyraldehyde, butyl acetate, ethyl acetate, isoamyl isovalerate, urea,

Table 2.—Average number of 50 adult female house flies resting on various colored cords tested against white cord and separately.[1]

Test Color	In Tests with White Cord		Tested Alone	Relative Attractiveness Index
	Color	White		
American Beauty Red	12.8	7.6	16.7	14.8
Black	10.0	5.9	16.3	13.2
Jungle Green	8.5	8.0	14.8	11.7
Powder Blue	9.5	5.9	12.7	11.1
White	—	6.3	13.6	10.0
Brilliant Yellow	7.5	5.6	—	7.5

[1] Results are averages of 40 observations.

[2] Tintex dyes, Park & Tillford, New York, N. Y. Trade names are used as a means of identifying the product. Their use does not constitute endorsement by the U. S. Public Health Service.
[3] Rohm & Hass Co., Philadelphia, Pa.

Table 3.—Average number of flies from various populations of resistant female house flies resting on various numbers of cords in cord testing chambers.

No. Cords (Linear Ft.)	Flies on Cords[1]			
	Flies in Test Population			
	10	20	40	80
3 (2.5 ft.)	0.7	2.8	5.1	7.3
6 (5.0 ft.)	2.1	3.4	7.5	12.1
12 (10 ft.)	2.7	4.6	10.2	22.4

[1] Figures are averages of four replicates of 20 counts each.

casein, diamalt, maltose, sucrose, glucose and ammonium carbonate. Butyl alcohol, butyraldehyde, isoamyl isovalerate and glucose increased the immediate attractiveness slightly but the effect was transitory, lasting less than 2 weeks.

Cords dipped in 1, 2, and 4 per cent suspensions of fly-egg homogenates showed some increased attractiveness. When soiled by regurgitation and fecal spots from exposure to 2000 flies for 2 to 4 days, cords attracted 26 out of 50 flies when tested alone, whereas clean cords attracted only 16 out of 50 flies. In competitive tests the clean cords attracted 13 flies, the soiled cords 18 flies. Since in field applications cords are rapidly covered with fly specks, the addition of chemical attractants appears to be of questionable importance in the light of the above experiments.

To determine the influences of population density and cord lengths available, flies resting on cords were counted using populations of 10, 20, 40, or 80 flies per cage and 2.5, 5.0, or 10 feet of white $\frac{3}{16}''$ cotton cord per cage. Twenty counts were made at 2-minute intervals using four separate cages. The insects were disturbed between counts and the cages were shifted so that no individual cage had the same population density for more than one replicate. The average numbers of flies resting on the cords under each set of test conditions (Table 3) were essentially equal when the factors of population density and linear feet of available cord were considered.

Cords without insecticides have been considered to this point. For insecticide impregnation, six 10″ lengths of cord were dipped for 1 minute in 100 ml. xylene solutions of the test compounds. Dyed cords were dried thoroughly before insecticide treatment. Preliminary evaluations with $\frac{3}{32}''$ white cotton cord were made using xylene solutions of parathion alone or combined with equal amounts of heptachlor at 0.3, 0.6, and 1.0 per cent. One day after treatment, 60-minute exposure gave complete mortalities of 3-day-old adult females. At 2 days after treatment the parathion cords gave complete mortality with 20-minute exposures but the parathion-heptachlor cords did not. All cords showed markedly less effectiveness at 1 and 2 weeks after treatment.

Cords treated with 1, 2, and 4 per cent solutions of parathion alone and combined with 5 per cent DDT were tested at 1, 3, 8, 12, 15, 18, and 21 weeks after impregnation using 120-minute exposures of the test flies. Cords treated with 1 per cent parathion failed after 3 weeks, those treated with 2 percent parathion failed at 8 weeks, while cords from the 4 per cent parathion treatment gave mortalities of over 90 per cent during the 21-week test period. When dipped in solutions containing 5 per cent DDT and 1 or 2 per cent parathion, treated cords failed after 8 weeks, while cords treated with 6 per cent DDT and 4 per cent parathion gave over 90 per cent mortality during the 21-week test period. Cords treated with 5 per cent DDT alone did not kill any of the flies.

The effects of the more attractive sizes and colors of cord and of higher concentrations of insecticide were investigated. White or red, $\frac{3}{16}''$ diameter cotton cords, treated with solutions of 5 or 10 per cent parathion and with 5 per cent parathion-5 per cent DDT, and white $\frac{3}{32}''$ diameter cord treated with 10 per cent parathion gave essentially complete mortality of test flies during a 41-week test at exposure periods of 60 minutes.

The percentage of flies on the cords during the 60-minute exposures (Table 4) indicate: (a) The $\frac{3}{16}''$ diameter treated cord was more attractive than the $\frac{3}{32}''$ diameter cord; (b) the red cords were slightly more attractive than the white cords; (c) the addition of DDT produced some repellent action; and (d) cords treated with 10 per cent parathion were less attractive than those with 5 per cent parathion. The per cent knockdown shows the $\frac{3}{16}''$ diameter cord to be better than the $\frac{3}{32}''$ diameter cord, the red cord to be more effective than the white cord, and

the addition of DDT increased the knockdown efficiency of the cord.

Of the insecticides evaluated, Diazinon also has shown promise for cord impregnation. Red $\frac{3}{16}$" cotton cords, treated with 5, 10, and 25 per cent Diazinon-xylene solutions, were tested over a 47-week period using 60-minute exposures of adult females of a DDT-resistant strain. Cords treated with 5 and 10 per cent Diazinon solutions gave more than 90 per cent mortality for 17 and 26 weeks after treatment, respectively. Cords dipped in 25 per cent Diazinon, or in 10 per cent parathion, were still giving 100 per cent mortality at 47 weeks when the tests were discontinued.

Both Diazinon and parathion showed some repellent action since only 20 to 22 per cent of the test flies were counted on the treated cords in contrast to 30 per cent on the untreated check cords. With the parathion-treated cords, only 67 per cent of the test flies were knocked down during the 60-minute test period. The Diazinon cords during the period of their effectiveness showed much higher knockdown activity; essentially all of the test flies were down within the exposure period. To determine whether the Diazinon was acting as a contact or a fumigant poison in producing the rapid knockdown on the flies, 18-week-old cords, treated with 25 per cent Diazinon, were wrapped with screen wire cylinders to prevent direct contact by the test flies. Within 50 minutes all of the flies were knocked down and complete 24-hour mortality was obtained. The wire cylinders were then removed from the treated cords for a second test during which a current of air was blown through the test cage to minimize fumigant action on the test flies. In this test 76 per cent of the flies were knocked down in 60 minutes and a 95 per cent mortality was obtained. The air stream reduced the number of flies on the cords by about one-third which undoubtedly reduced knockdown and mortality results. The initial test, however, indicated a strong fumigant action by Diazinon.

Table 4.—Average percentage of flies on cords and knocked down during 60-minute exposures to various cords treated with parathion or a parathion-DDT combination.[1]

Type of Cord			Per Cent on Cords	Per Cent Knock-Down
Color	Diameter (inches)	Treatment		
White	3/32	10% parathion	10	44
White	3/16	10% parathion	18	50
Red	3/16	10% parathion	20	67
Red	3/16	5% parathion	24	52
Red	3/16	5% parathion 5% DDT	16	67
Red	3/16	Check	26	0

[1] Results are averages of 14 tests made at regular intervals over a 41-week period.

Table 5.—Average per cent knockdown and 24-hour mortality of 50 adult female DDT-Resistant house flies following 1-hour exposures to cords impregnated with various combinations of parathion and Diazinon.

Cord Treatment		Period of Time (Weeks)					
Per Cent Parathion	Per Cent Diazinon	4	8	12	16	21	26
		Knockdown (per cent) in 60 minutes					
10	—	69	71	75	34	22	34
7.5	2.5	79	99	96	43	54	52
5.0	5.0	99	97	100	81	78	89
2.5	7.5	100	100	100	66	62	61
—	10	100	100	100	47	18	—
		Mortality (per cent) in 24 hrs.					
10	—	100	100	100	98	98	100
7.5	2.5	100	100	100	98	98	100
5.0	5.0	100	100	100	100	100	100
2.5	7.5	100	100	100	94	94	100
—	10.0	100	100	100	69	34	—

Combinations of parathion and Diazinon were tried to determine whether Diazinon would give faster knockdown action over an extended period of time. The results (Table 5) show that the substitution of Diazinon for parathion improved the knockdown effectiveness of the combinations up to the most effective combination of 5 per cent parathion-5 per cent Diazinon. All of the treated cords gave 94 to 100 per cent kill of the test flies during the 26-week period except the cords treated with 10 per cent Diazinon, which failed at 16 weeks.

Cords impregnated with the following insecticides failed to give at least 50 per cent mortality at 1 week after treatment: 10 per cent solutions of CS-708, DDT, NPD[4], nicotine, A-42[5] and malathion. Cords treated with 25 per cent NPD gave 75 per cent mortality at 1 week after treatment, but only 12 per cent mortality at 4 weeks. Cords treated with 10 per cent EPN gave 74 per cent mortality at 1 week but were highly repellent. Cords treated

[4] Tetra-n-preopyl dithionopyrophosphate, a product of E. I. DuPont de Nemours and Co., Wilmington, Del.

[5] Arsenomethane As-1, 2 disulfide, an experimental product of American Smelting and Refining Co., New York, N. Y.

with 5 and 10 per cent Bayer 21/199[6] gave complete control for 1 and 3 weeks repectively, and more than 70 per cent mortality for 13 weeks and 17 weeks. Cords treated with 10 per cent Bayer L13/59[6] gave better than 70 per cent mortality for 3 weeks only.

DISCUSSION.—Based on the tests described, the basic fiber of the cord, the diameter and color of the cord, and the effect of attraction additives are important factors in selecting cords for insecticidal impregnation. This is illustrated by comparing the average numbers of flies on different type cords, since the $\frac{3}{32}''$ wool cord attracted less than 2 per cent of a test population, the $\frac{3}{32}''$ cotton cord attracted 9 per cent, the $\frac{3}{16}''$ white cotton cord attracted 17 per cent, the $\frac{3}{16}''$ red cotton cord attracted 30 per cent, while the $\frac{3}{16}''$ red cotton cord covered with fly specks attracted somewhat more than 50 per cent of the test flies. The effect of more attractive strings should be reflected in the speed with which field populations of flies are reduced.

The halogenated hydrocarbon insecticides have not proved favorable for cord impregnation because the test flies possessed considerable resistance to these compounds. The two promising compounds at present, parathion and Diazinon, have these properties in common: (1) They are organic phosphorus compounds which are liquids at normal room temperatures, (2) they have pronounced fumigant action, (3) they are fairly volatile and have not shown prolonged residual action when tested as residues on surfaces, and (4) they show rapid action so that a lethal dose is obtained by insects within a relatively short exposure periods. Where resistance to the halogenated hydrocarbons is limited, these insecticides may show effectiveness on the cords (Chow & Thevasagayam 1953) and on strips of metal screen (Pimentel *et al.* 1951).

In field use the parathion cords have given promising results (Maier & Mathis),[7] (Kilpatrick *et al.*),[8] and have been successful in reducing the fly populations to relatively low levels. In view of the tests with various population densities and various amounts of available cords, and the fact that the cords must compete with other resting surfaces under field conditions, the linear feet of cord per establishment appears to be a controlling factor.

SUMMARY.—Some factors influencing the attractiveness of cords to house flies were investigated in laboratory studies. Sisal or cotton cords were more attractive than jute or wool cords. Attractiveness of the cords increased with cord diameter in tests with cords ranging from $\frac{3}{64}''$ to $\frac{7}{16}''$ diameter. Red or black cords were preferred to green, blue, yellow, or white cords. Cords soiled with fly fecal spots had more attraction than cords treated with a variety of chemical attractants.

In studies with different population densities and various amounts of available cord the numbers of flies resting on the cords were essentially equal if the factors above were considered.

In tests with insecticide-impregnated cords, those dipped in 5 or 10 per cent parathion-xylene solution gave essentially complete mortalities of DDT-resistant house flies with 60-minute exposures during 41-week test period. Cords treated in 5, 10, or 25 per cent Diazinon-xylene solution gave more than 90 per cent mortality for 17, 26 and over 47 weeks respectively. Cords treated with 5 per cent parathion and 5 per cent Diazinon showed high mortalities and rapid knockdown action during a 26-week test period.

Cords treated with CS-708, DDT, NPD, nicotine, A-42, malathion, EPN, Bayer 21/199, and Bayer L13/59 showed less promising results than cords treated with parathion and Diazinon.

[6] Experimental products of Farbenfabriken Bayer Laboratory c/o Robert J. Geary, Blue Point, Long Island, N. Y.
Bayer 21/199 is 3-chloro-4-methylumbelliferone 0,0-diethyl thiophosphate.
Bayer L 13/59 is 0,0-dimethyl 2,2,2-trichloro-1-hydromethylphosphonate.

[7] Maier, P. P. and Willis Mathis. Fly Control at Dairies with Parathion Impregnated Cords. (In manuscript.)

[8] Kilpatrick, J. W., H. F. Schoof and P. P. Maier. Further Studies on the Use of Parathion Impregnated Cords for House Fly Control in Dairy Barns. (In manuscript.)

LITERATURE CITED

Chow, C. Y., and E. S. Thevasagayam. 1953. A Simple and Effective Device for Housefly Control with Insecticides. Bul. World Hlth. Org. **8**: 491–5.

Pimentel, David, H. H. Schwardt and L. B. Norton. 1951. New Methods of House Fly Control in Dairy Barns. Soap and Sanit. Chem. **27**(1): 102.

Are Cotton Insects Becoming Resistant to Insecticides?

E. E. Ivy and A. L. Scales, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*[1]

During the last several years there have been numerous complaints from growers that the organic insecticides are not so effective as they were several years ago. In the last two years most of these complaints have been of failure to control the cotton leafworm, *Alabama argillacea* (Hbn.), and various species of spider mites, However, failures to control the boll weevil, *Anthonomus grandis* Boh., the bollworm, *Heliothis armigera* (Hbn.), the cotton aphid, *Aphis gossypii* Glov., and several other cotton pests have also been reported.

Many of these failures, of course, may be attributed to faulty applications; or to applications made too late for control, under adverse weather conditions, at too low a dosage, with too long an interval between applications, or with poor formulations. However, the repeated and increasing frequency of reported failures to control the cotton leafworm, which has long been regarded as one of the most easily controlled cotton insects, lead one to wonder if leafworms in some way may have become resistant to the chlorinated hydrocarbon insecticides used for their control.

Development of resistance to insecticides is by no means confined to house flies, mosquitoes, lice, and other insects of importance to the medical entomologist. Babers (1953) mentions many agricultural pests that have developed insecticide resistance. The evidence of resistance with the imported cabbage worm, *Pieris rapae* (L.) (McEwen & Chapman 1952), the oriental fruit fly, *Dacus dorsalis* Henden in laboratory exposures (Carter 1952), and several species of spider mites (Smith 1952) seems especially well documented.

Some data are present on several cotton insects collected in connection with the insecticide screening program carried on at Waco and College Station, Texas, since 1946.

Cotton Leafworms.—In fields-cage toxicity tests conducted at Waco in 1946 (Ivy *et al.* 1947), when toxaphene was being evaluated against cotton insects for the first time, the following mortalities of cotton leafworms were obtained:

Pounds per Acre	*Per Cent Kill*
1.6	99
0.8	95
0.4	77
0.2	59

Substantially the same results were obtained with toxaphene the next year at Waco, and for the next several years at College Station, when the screening work was moved there. After following a fairly consistent pattern for several years, in 1951 the leafworms appeared to have suddenly become somewhat harder to kill. A rather extensive series of tests were therefore made in 1952 and 1953 to determine whether leafworms had become resistant to toxaphene. The results of these tests are summarized in table 1.

Table 1.—Per cent kill of cotton leafworms with toxaphene applied at various rates per acre in cage texts in Texas

Locality and Year	4 Pounds	2 Pounds	1 Pound	0.5 Pound
Waco 1947	—	100	93	81
College Station:				
1948	—	95	—	—
1949	—	98	99	86
1950	—	99	78	83
1951	—	70	—	—
1952	95	79	70	37
1953	79	52	30	4
Port Lavaca 1953	84	52	38	6

Dosage-mortality lines derived from some of these data indicate that the lethal dosages were as follows:

		Pounds per Acre	
Locality	*Year*	*LD-50*	*LD-90*
Waco	1946	0.17	0.60
College Station	1952	0.79	3.99
	1953	1.82	6.37
Port Lavaca	1953	1.62	5.85

In 1953 the Port Lavaca strain was collected from treated fields, and the College Station strain from untreated fields. The data show no difference in susceptibility

[1] In cooperation with the Texas Agricultural Experiment Station.

between the two strains, but that both strains were about twice as hard to kill as the larvae collected in 1952, and approximately 10 times as resistant as those in 1946. Nearly complete control can still be obtained, however, with 10 pounds of calcium arsenate or 0.1 pound of parathion per acre.

Larvae surviving the toxaphene treatments were saved, and it was planned to conduct tests with their progeny to see whether resistance could be further increased. However, in a widespread general infestation of leafworms in the area so many eggs were laid on all the cotton available for leafworm food, that the cultures could not be maintained without getting them mixed with the outside population, and this work was discontinued.

It is difficult to see how leafworms could become resistant to toxaphene in this country, since the population dies out each year. The only other possibility is that resistance has developed in Central and South America, and that moths developing from the resistant worms have migrated here. If this is true, cotton growers in Central and South America should be persuaded to stop using toxaphene and other chlorinated hydrocarbons, and to use calcium arsenate or parathion instead for a few years in an attempt to prevent a further increase in resistance. Perhaps the leafworm might then revert to its susceptible state.

SPIDER MITES.—In connection with toxicity tests conducted against the tumid spider mite, *Tetranychus tumidus* Banks, during the last quarter of 1952, it was observed that higher dosages of parathion and several of the other phosphorus compounds were required than in previous years. Difficulty had been experienced in maintaining the culture during the summer and early fall, presumably owing to a contamination of the laboratory building with various volatile phosphorus compounds. Resistance to phosphorus compounds may have been accidentally induced in our laboratory culture when it was maintained in the contaminated laboratory.

To check on this point, another culture of this mite was obtained from the greenhouse. This culture promptly declined when brought into the laboratory, in contrast with the laboratory strain, which was reproducing nicely at that time. This change seemed to confirm our suspicion that the laboratory culture had acquired an immunity. Both cultures were then taken to the greenhouse, where a series of tests were conducted in January and February to compare the susceptibility of the two strains to parathion. The results were as follows:

	Pounds per Acre	
Strain	*LD-50*	*LD-90*
Greenhouse	0.006	0.022
Laboratory	0.008	0.121

At the LD-90 level the laboratory strain was much more resistant than the greenhouse strain. There was less difference at the LD-50 level. This indicated that resistant individuals in the population were not affected by even increased dosages of parathion.

To determine whether resistance could be increased still further, each of these cultures was divided on January 29, and half of each culture was treated with an approximate LD-99 dosage of parathion. For the greenhouse strain this dosage was 0.0625 pound, and for the laboratory strain 0.25 pound per acre. Several thousand individuals were treated in each of the cultures. Survivors were permitted to reproduce, and on February 27 the cultures had built up to the point that the process could be repeated. After the cultures had built up again on March 18, they were treated for the third time. The untreated original cultures were maintained in an adjacent cage in the greenhouse and a water moat was used to insure that the cultures did not become mixed.

Dosage-mortality tests conducted with each of the cultures in April gave the following results:

	Pounds per Acre			
	Untreated		*Treated 3 Times*	
Strain	*LD-50*	*LD-90*	*LD-50*	*LD-90*
Greenhouse	0.014	0.036	0.167	0.462
Laboratory	0.038	0.116	0.102	0.513

The laboratory culture which at the the LD-50 was more than five times as resistant as the greenhouse culture during February, was now approximately 14 times as resistant, and $4\frac{1}{2}$ times as resistant as an untreated laboratory culture. The greenhouse culture likewise increased

its resistance so that it was almost as resistant as the laboratory culture.

In a continuation of these the cultures that had received three treatments were divided, and half of each was treated with a calculated LD-99 dosage of parathion to determine whether resistance could be increased still further. The remaining half was maintained untreated to determine whether resistance would persist.

For some reason, all the cultures became easier to kill in May and June. The calculated dosage for the LD-99 was approximately 1 pound per acre, and when this dosage was used all the mites were killed.

The three-treatment cultures were again divided and treated at the rate of 0.75 pound per acre, but again all the mites were killed. At this time the mites were reproducing very slowly, and owing to the hot, dry weather even the untreated cultures were maintaining themselves with difficulty. The greenhouse was then covered with wooden slats, all the benches were filled with water, the walks and floors were kept wet to maintain a higher humidity, and 0.5 pound per acre was tried. A few mites survived this treatment. In July, after they had built up a sizable population, the 0.5-pound dosage was repeated. The last treatment was made in August, and data for deriving the dosage-mortality lines were obtained in September. The results were as follows:

	Pounds per Acre					
	Untreated		*Treated 3 Times*		*Treated 6 Times*	
Strain	*LD-50*	*LD-90*	*LD-50*	*LD-90*	*LD-50*	*LD-90*
Greenhouse	0.100	0.411	0.279	1.457	0.320	0.961
Laboratory	0.141	0.481	0.383	1.042	0.289	1.156

It will be noted that the strains which had received six treatments were no more resistant than those which had received only three treatments. However, the untreated cultures had also become much harder to kill than they were in the earlier tests, so that now the resistant strains were only two or three times as resistant as the susceptible strains. We are at a loss to account for this. It is possible that rearing these mites in cages adjacent to cages of mites treated with parathion caused resistance to develop. The study is being carried further to determine whether resistance can be further increased.

COTTON APHIDS.—No resistance has been encountered in cotton aphids at College Station. A culture of aphids reported to be resistant to BHC was received from South Carolina in the summer, and was compared with our local strain in August and September. The results with various dosages of the gamma isomer were as follws:

	Per Cent Kill	
Pounds per Acre	*College Station Strain*	*South Carolina Strain*
0.5	71	75
0.25	45	80
0.125	28	59
0.0625	10	16

Dosage-mortality lines were derived from these data, and the calculated lethal dosages were as follows:

	Pounds per Acre	
Strain	*LD-50*	*LD-90*
College Station	0.26	1.03
South Carolina	0.15	0.73

The South Carolina strain did not appear to be resistant; in fact, it was slightly easier to kill than our local strain of aphids.

BOLLWORMS AND BOLL WEEVILS. No resistance has been encountered in either of these species. In the field-cage tests approximately the same amount of DDT was required to kill bollworms as in the initial work 10 years ago. Approximately the same kill was obtained with 2, 1, or 0.5 pound of toxaphene as with the first sample tested in 1946.

With the boll weevil the picture is slightly more complicated, because of its seasonal variation in susceptibility (Rainwater & Gaines 1951). In 1953, when tested against weevils reared in squares in June, both BHC and toxaphene showed

about the same toxicity as when the initial work was done with these insecticides in 1945 and 1946. Late-season tests conducted during 1953 also compare very closely with late-season tests conducted in other years.

LITERATURE CITED

Babers, Frank H. 1953. Chemical control and resistance to insecticides by agricultural pests. JOUR. ECON. ENT. **46**(5): 869–73.

Carter, Walter. 1952. Recent developments in oriental fruit fly research. JOUR. ECON. ENT. **45**(2): 274–9.

Ivy, E. E., C. R. Parencia, Jr., and K. P. Ewing. 1947. A chlorinated camphene for control of cotton insects. JOUR. ECON. ENT. **40**(4): 513–7.

McEwen, F. L., and R. K. Chapman. 1952. Imported cabbage worm resistance to insecticides. JOUR. ECON. ENT. **45**(4): 717.

Rainwater, C. F., and J. C. Gaines. 1951. Seasonal decline in the effectiveness of certain insecticides against the boll weevil. JOUR. ECON. ENT. **44**(6): 971–4.

Smith, Floyd F. 1952. Spider mites and resistance. *In* Insects, U. S. Dept. Agr. Yearbook **1952**, pp. 652–6.

Correlation between the Length of the Larval Period of *Musca domestica* L. and Resistance of Adult Flies to Insecticides[1]

R. E. MCKENZIE[2] and W. M. HOSKINS

Attempts by numerous experimenters to find morphological or physiological differences between DDT-susceptible and DDT-resistant house flies have met with relatively little success. Thus the exceptionally thick and heavily pigmented tarsi and pulvilli in resistant house flies in Sweden reported by Wiesmann (1947) have not been found in certain American strains (March & Metcalf 1950). Also, among four strains absorption of DDT was slightly slower into the most susceptible after topical application (Perry & Hoskins 1951), instead of the reverse, as would be expected if differences in the integument are important.

It was noted by Bruce (1949) that certain resistant strains required one to two days longer for the change from egg to adult. March & Lewellen (1951) found the average life cycle of a highly resistant Bellflower strain to be 14.1 days in comparison with 13.9 days for their susceptible strain, but they thought this not to be significant. Pimentel *et al.* (1951) reported a longer larval period in four DDT-resistant strains than in a susceptible one and that the increases were roughly proportional to the resistance. They also made the important discovery that in each strain the flies coming out during the first 48 hours of the emergence period had a smaller LD 50 by exposure to residual deposit than those emerging in the last 48 hours of the period. They found no difference in number of eggs, hatching period, fertility, length of pupal period, pupal weight, sex ratio, preovipositional period or length of adult life. Similar observations had been made, but not on a quantitative basis, during rearing of a half dozen strains of various degrees of resistance at Berkeley.

Thus there appeared to be good reason to believe that selection for resistance to DDT by exposure to the chemical results in flies which have a lengthened larval period, and that within a colony there is some difference in susceptibility between the early and the late emerging adults. The object of the work to be reported was to determine if successive selection of early and late pupae would result in splitting a strain into two substrains differing markedly in susceptibility to DDT or, in other words, whether resistance can be developed without exposure to the chemical.

INSECTS AND METHODS USED.—The two laboratory strains of *Musca domestica* selected for these experiments have

[1] Contribution from the laboratory of insect physiology and toxicology, Department of Entomology and Parasitology, University of California, Berkeley, California. (Studies on Resistance to Insecticides—V).

[2] Present address: Agricultural Chemicals, Carbide and Carbon Chemicals Company, 30 East 42nd Street, New York.

been called the Super Laton, hereafter referred to as SL, and the Berkeley or B. Their previous histories may be summarized as follows.

The Laton colony, taken from a dairy near San Jose, California, in 1948 when control obviously was bad, was bred for a few generations at the Stauffer Chemical Company's Research Laboratory in Los Altos and then for 22 generations at Berkeley. Since methods for determining susceptibility had not been standardized, it is impossible to set the original tolerance, but it probably was at least 2 μg./female fly by the topical application of acetone solution of DDT to the dorsal thorax. By July, 1949, the LD 50 had dropped to 0.50 μg. One or two selections by spraying adults with a kerosene solution of DDT in the small spray chamber (Hoskins & Caldwell 1947) raised the LD 50 for topical application to 2.50 μg./female as reported by Perry & Hoskins (1951), who called the selected strain SL. By March, 1951, this LD 50 has declined to 0.7 μg. Thus the strain has a record of declining in resistance to DDT twice during a 3-year period in which eggs for the next generation were taken whenever convenient during the normal laying period and most, but not all, pupae were taken from the rearing jars.

The B strain started in 1947 from wild flies caught in Berkeley and was reared continuously without exposure to any insecticide except as noted below. The first definite measure of DDT susceptibility by topical application of acetone solution gave an LD 50 of 0.03–0.05 μg. in 1948 and 0.05 μg. was repeatedly found in 1949–50. During the latter year an accidental exposure to aldrin vapor killed about half the females and most of the males of the breeding colony. The LD 50 for DDT immediately thereafter was 0.15 μg. This has varied only slightly since, e.g., a value of 0.23 μg. was obtained in January, 1953.

These two strains thus present considerable contrast in their previous relations with DDT. The SL has been exposed frequently and showed ability to segregate resistant individuals rapidly but to lose resistance under ordinary laboratory rearing. The B strain has had no exposure to DDT and has shown only a slight tendency to increase in resistance during laboratory breeding. It thus seemed that the results of selecting for early and late pupae in the two strains would offer interesting contrasts and perhaps indicate the generality of the effect.

All rearing was done in a small room with forced air circulation and ventilation maintained at 26±1° C. and approximately 50 per cent relative humidity. Adults were kept in colonies of about 1,500 (except when smaller numbers emerged) in screen cages 1 foot on an edge. Those used for breeding were offered cube sugar and evaporated milk diluted three fold. This was put in a 100 ml. beaker which was inverted over a layer of absorbent cotton held in a petri dish. Two drops of formalin were added and a fresh preparation was put in a cage each day. First eggs were laid on the cotton on the third or fourth day, and thereafter a full strength colony would produce from 2,000 to 5,000 eggs per day. By withholding the milk for a day, during which eggs were not laid, a larger number would be obtained on the next day. The practice was to take a large batch of eggs on the fourth or fifth day, withhold milk 1 day, and then obtain another large batch within a 4-hour period for propagation of the colony. To avoid selection from a few females, the whole day's output of eggs was thoroughly dispersed in water, and about 2,100 eggs, corresponding to 1.3 ml. volume in a marked pipette, were withdrawn.

For larval rearing, 500 grams of CSMA fly-rearing medium thoroughly mixed with 1 liter tap water were put into a glass jar 8½ inches across by 5 inches deep. The 0.3 ml. fly eggs suspended on 10 ml. water were dispersed over the surface of a shallow crater in the medium and the surface was levelled. Cheesecloth held over the jar by a rubber band both retarded evaporation and prevented egglaying by any fly which might be free in the rearing room. Each day the upper inch of the medium was loosened to prevent caking. In case of the strains exposed as larvae to DDT, the latter was added with thorough mixing at the desired rate as a 50 per cent DDT wettable powder. Concentrations are calculated as p.p.m. of dry medium, e.g., 2.00 grams of wettable powder in 500 grams medium gives 2,000 p.p.m. DDT. Since adult flies from larvae which have been exposed to DDT contain considerable amounts of both DDT and DDE in their tissues (Tahori & Hoskins 1953), it

was necessary to rear two colonies of the DDT strains for each generation whose susceptibility was to be measured. One was exposed to the chemical as described above, and used as breeding stock, the other was reared without exposure and tested as adults.

As pupation time approached, the jar was checked frequently but with minimum disturbance to detect the first few pupae. Since migration of fully fed larvae to the upper layer of the medium occurs 4 to 8 hours before pupation, the beginning of this process can be anticipated closely. Nonetheless, pupation sometimes began at night and many pupae were present upon examination early in the morning. Fortunately there is a definite time sequence in the coloring of pupae, taking zero hour as the time when the larva assumes the pupal form, as follows: 1 hour, yellow to light buff; 1 to 2 hours, buff; 2 to 4 hours, light rusty brown; 4 to 6 hours, rusty to slightly reddish; 6 to 8 hours, reddish brown with some darkening at ends of the puparium; 8 to 12 hours, darker but reddish tinge persists; 12+ hours, final dark brown to black color. Since the uncertain period at night was 8 to 10 hours long, it was possible by observation of the darkest pupae to fix the time of their pupation with an uncertainty of not over 2 to 3 hours. Similarly, the time when approximately 50 per cent had pupated and the time of last pupation could be determined. For the purpose of comparing the various substrains, the total interval in hours from the middle of the 4-hour oviposition period to first pupa, to 50 per cent pupation and the total pupating period, i.e., total spread from first to last, were calculated. In some cases, a few small and obviously undernourished larvae remained when the others had pupated. These were neglected in calculating time of last pupation and total pupating period.

Except when selection for early or late pupation was made, the pupae were left undisturbed in the medium for 3 days, when they were separated by screening and blowing away the dried particles of medium. Three lots of 100 pupae each were weighed and all were transferred to a wire cage supplied with sugar and water if the colony was to be used for testing susceptibility or with sugar and diluted milk if used for egg production.

The procedure for starting the various selected substrains of the SL strain was as follows. On April 4, 1951, in addition to the normal culture which may be taken as generation 1 of the check strain, a second was separated into the first day's pupae, approximately 900, which gave rise to the SL Early substrain, and into those which pupated in the next 3 days from which the SL Late substrain arose. In succeeding generations an attempt was made to select the first 500 to 700 pupae in each SL Early colony, but occasionally either more or less strict selection was the best that could be done. Similarly, with the Late substrain, after 50 to 75 per cent had pupated, the remaining larvae were taken as the breeding stock. The LD 50 values were determined, however, on samples taken from the whole colony in each case in order to obtain a measure of the average susceptibility and avoid the differences known to exist between the early and late individuals of a given generation. Lastly, a colony with 2,000 p.p.m. DDT in the medium was started, giving rise to the SL DDT substrain. This concentration was raised by steps ultimately to 8000 p.p.m. as resistance increased.

The substrains of the B flies were selected in the same manner, except that concentrations of DDT in the larval medium were raised from 1,500 p.p.m. at first to only 3,000 p.p.m. after 10 generations.

Since a large number of dosage-mortality tests were to be made, topical application was abandoned in favor of the much quicker small vial technique (Hoskins *et al.* 1951). In brief, the chosen amount of DDT is deposited on the inner surface of a shell vial from petroleum ether solution containing 1 mm.^{3} refined light spray oil, 70 seconds Saybolt viscosity. Female flies from a test colony 4 to 6 days old are collected in groups of 25 while under light carbon dioxide anesthesia. They are allowed to recover for 1 hour, introduced into the vials, left for 1 hour and then transferred to screen holding cages. Water and sugar are supplied and mortality is determined after 24 hours. When necessary, affected but living flies are classified as surviving or dead in accordance with accumulated experience gathered from longer observation periods. Suitable amounts of DDT were taken to spread the mortalities above and below the 50

Table 1.—LD 50's in μg. DDT/vial, time in hours from oviposition to mid-point of pupation period, and total interval from first to last pupation for four substrains of Super Laton house flies.

	Substrain											
	Check			Early			Late			DDT[2]		
Generation[1]	Oviposition to Mid-Pupation	First to Last Pupation	LD 50	Oviposition to Mid-Pupation	First to Last Pupation	LD 50	Oviposition to Mid-Pupation	First to Last Pupation	LD 50	Oviposition to Mid-Pupation	First to Last Pupation	LD 50
1	158	67	16	—	—	20	—	—	18	—	—	—
3	144	48	15	—	—	20	163	57	—	144	48	—
4	144	48	—	—	—	—	161	62	24	144	48	50
5	144	48	17	—	—	19.5	176	80	25	144	48	76
6	158	67	—	—	—	—	175	82	40	144	48	125
7	144	48	19	—	—	—	176	80	35	150	60	150[3]
9	145	46	—	120	30	—	—	—	—	166	52	—
11	145	44	13	—	—	11	—	—	125	—	—	—
13	141	54	—	—	—	11	200	79	—	132	24	130
15	154	28	18	—	—	10	218	93	140	156	[4]	—
17	164	56	—	110	21	—	216	96	120	180	72	130
20	164	55	—	128	41	13	272	175	110	166	52	—
22	151	34	—	139	58	12	—	—	—	132	[4]	—
24	163	58	18	139	37	14	258	155	100	144	48	130
26	164	56	18	—	—	12				142	51	—
27	154	75	—	—	—	—				180	120	120

[1] Results with generations not shown were less complete, but consistent with those in the table.
[2] Data for DDT substrain are for test colonies which were reared on DDT-free diet as explained in text.
[3] Exceptionally large flies.
[4] Too few flies for first to last pupation to be significant.

per cent level with each substrain.

Dosage-mortality data are plotted on log dosage-probit paper for estimation of LD 50 values, which are expressed as micrograms of toxicant per vial. For reduction to micrograms per fly, these may be multiplied by the factor 0.8/25 to allow for the proportion picked up and the number of flies used. For calculation of such statistical properties as adequacy of fit, slope, standard error and confidence limits, the graphical methods of Litchfield & Wilcoxon (1949) have been employed. Other toxicants were handled in the same way as DDT.

RESULTS.—The data showing the relation between the period from oviposition to 50 per cent pupation, length of the period in which pupation occurred (the pupating period), and the LD 50's for DDT are given in tables 1 and 2 for all substrains of the Super Laton and Berkeley flies. Blank spaces indicate that the corresponding observations were not made. The average pupal weights of all groups included in the above-mentioned tables are as follows: SL Check (16.0–24.3), 20.1; SL Early (15.6–24.2), 19.0; SL Late (16.3–22.3), 18.8; SL DDT (16.5–24.0), 21.3 and B Check (16.0–18.2), 17.1; B Early (15.4–18.3), 17.1; B Late (16.3–17.7), 17.0; B DDT (16.5–20.2), 18.5 mg. With both strains, the colony exposed to DDT in the larval medium was slightly heavier than the unexposed pupae. Since the groups used in mortality tests were

Table 2.—LD 50's in μg. DDT/vial, time in hours from oviposition to mid-point of pupation period, and total interval from first to last pupation for four substrains of Berkeley flies.

	Substrain											
	Check			Early			Late			DDT[1]		
Generation	Oviposition to Mid-Pupation	First to Last Pupation	LD 50	Oviposition to Mid-Pupation	First to Last Pupation	LD 50	Oviposition to Mid-Pupation	First to Last Pupation	LD 50	Oviposition to Mid-Pupation	First to Last Pupation	LD 50
1	159	30	11	163	59	—	162	59	—	—	—	—
2	—	—	—	150	58	—	174	81	—	177	25	32
3	170	44	10	—	—	—	—	—	—	166	56	32
4	146	47	—	—	—	—	175	81	25	151	50	—
5	145	49	—	—	—	—	168	48	28	163	66	43
6	142	51	—	—	—	—	180	73	—	165	79	39
7	159	24	—	—	—	—	192	93	—	176	80	34
8	166	52	11.5	136	27	—	196	71	30	190	100	30
9	—	—	—	132	50	10.5	189	55	30	168	48	38
10	168	96	—	145	44	8.5	188	76	—	—	—	—
11	168	96	—	142	53	—	193	87	—	158	55	—

[1] Data for DDT substrain are for test colonies which were reared on DDT-free diet as explained in text.

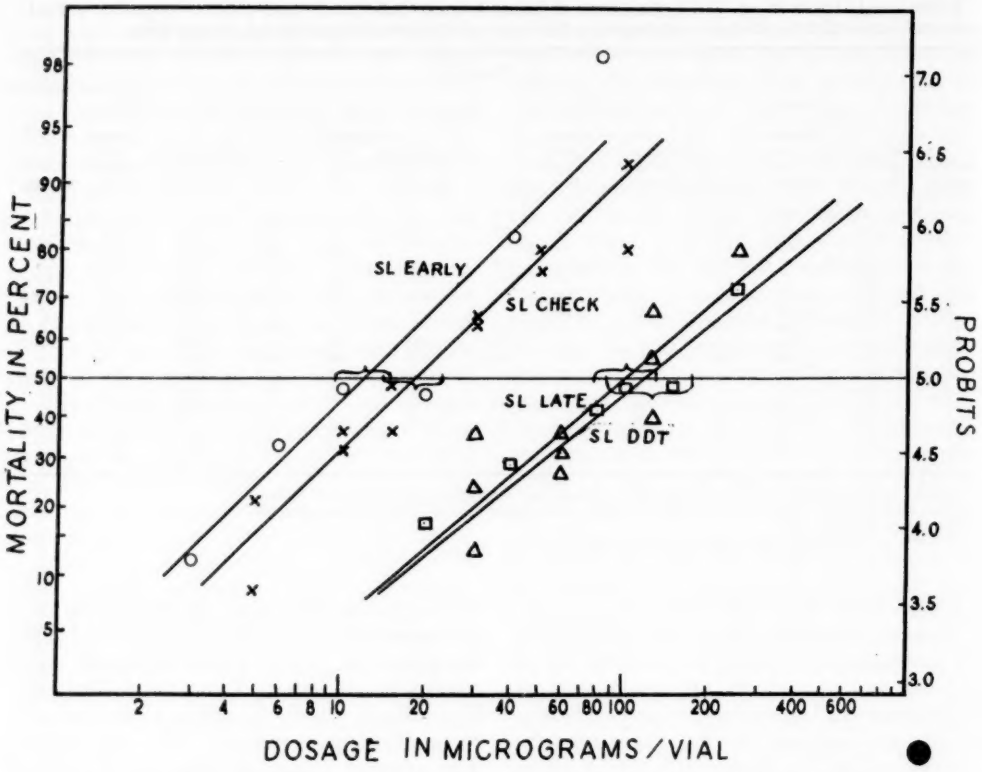


FIG. 1.—Dosage-mortality lines for the four Super Laton substrains exposed to DDT by the small vial method. ○, SL check; ×, SL early; △, SL late; □, SL DDT.

not reared in DDT-contaminated medium, the difference in pupal weight could not be due to a selective action of the toxicant in the generation tested. It is obvious that the "Late" substrains were not heavier than the unselected Checks. The B pupae were lighter in general than those of the SL strain. No systematic change in pupal weight occurred during the course of the experiments.

Table 1 shows that selection of late pupae of the SL strain resulted in a lengthening of the period from oviposition to midpupation and of the pupating period by at least 50 per cent. The resistance as measured by LD 50 simultaneously increased 6 to 8 fold. Exposure of larvae to selective action of DDT raised the LD 50 to approximately the same level but had little, if any, effect upon the length of the prepupal or pupating periods. Selection of early pupae reduced the periods and the LD 50 slightly as compared with the check colony. All effects were similar but much less in magnitude with the Berkeley flies.

It would be expected that the early and the late pupae of a *single colony* would gives rise to flies having different susceptibilities to the toxicant. This matter was not studied in detail, but in four cases with the SL flies, namely the first Check generation, and the fourteenth, nineteenth and twentieth generations of the Late substrain, the ratios of LD 50 for flies from the second cut of pupae to that for those from the first cut were 1.4, 1.4, 1.8, and 2.7. The precise magnitude of the ratio is of no significance, for it varied with the point at which the two groups were separated, but the important point is that the later pupating individuals always produced flies with a higher LD 50.

To illustrate the dosage-mortality data, the results obtained with DDT for the last generations of the SL flies are shown in figure 1. Corresponding data for the last tests made with the B flies are given in figure 2. Confidence limits for LD 50 values as calculated by the graphic methods of Litchfield & Wilcoxon (1949) are

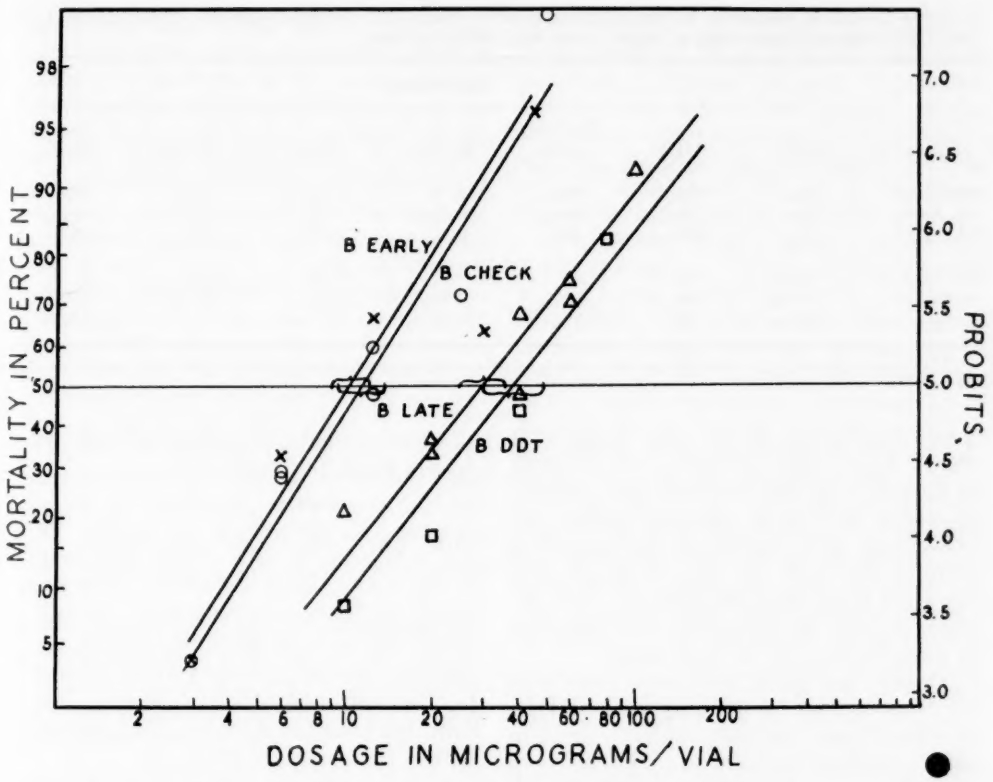


FIG. 2.—Dosage-mortality lines for the four Berkeley substrains exposed to DDT by the small vial method. ○, B check; ×, B early; △, B late; □, B DDT

indicated by brackets. During the time when the resistance was increasing with the first 8 to 10 generations of the SL Late and DDT flies, the slopes changed from that of the Check substrain to those shown. Unfortunately, observations were not made at the proper time to note this effect with the B substrains.

The dosage-mortality lines of figures 1 and 2 show that the Late (and DDT) substrain is widely removed from the Check with both SL and B flies, but the Early and Check overlap. These results, of course, are for only one generation of each substrain and when the similar differences found at each generation are considered, it becomes much more certain that the Early substrain differs slightly from the Check and the Late is markedly different. The slopes shown in figures 1 and 2 are the composites for all later generations with the Late and DDT substrains and for all generations with the Check and Early substrains. They also are statistically valid for the generations used as illustrations.

To illustrate the procedure, the complete calculation for the SL Check substrain, which is represented in figure 1, may be given as follows:

slope function, $S=(LD84/LD50+LD50/LD16)/2$
$=(64/18+18/5.1)/2=3.54$

number of insects used between 16 and 84% mortality, $N'=10\times25=250$

factor for LD50, $f\ (LD50)=3.54^{2.77/250}=3.54^{0.175}$
$=1.248$

Hence, confidence limits for LD50, c. l. (LD50) = 18/1.248 to 18×1.248 or 14.4 to 22.4, as indicated by the bracket in figure 1.

Total Chi^2 calculated as summation of squares of deviations of observed from expected mortalities is 6.2. Since the degrees of freedom are 10, i.e., two less than the number of doses, the permissible value of Chi^2 for 95% confidence is 18.3 and therefore the line is consistent with the data

Litchfield & Wilcoxon (1949) have suggested that slopes be expressed as $(LD\,84/LD50 + LD50/LD16)\div 2$, which amounts to calculating the change in log dosage per unit change in probit. In these terms, the slopes of dosage-mortality lines for the eight substrains used are: SL Check 3.54 (0.282); SL Early 3.41 (0.293); SL Late

Table 3.—LD 50 values for seven insecticides other than DDT obtained with the Check, Early, Late and DDT-exposed substrains of Super Laton and Berkeley flies.[1]

Substrain	Insecticide						
	DDT	DDD	Methoxychlor	Lindane	Aldrin	Dieldrin	Pyrethrins
SL Check	18_{26}	35_{27}	$16_{26,27}$	1.0_{2}	$0.4_{23,24}$	0.4_{24}	13_{27}
SL Early	12_{22}	$30_{21,25}$	$14_{24,25}$	0.7_{20}	0.4_{20}	0.4_{20}	$9_{25,26}$
SL Late	110_{20}	$290_{19,23}$	38_{19}	$0.8_{17,18}$	$0.4_{19,22}$	$0.5_{19,20}$	13_{22}
B Check	11.5_{8}	38_{3}	14	—	0.4_{3}	0.3_{3}	11.5_{3}
B Early	8.5_{10}	$38_{9,10}$	$17_{9,10}$	0.4_{10}	0.3_{9}	0.3_{10}	$14_{9,10}$
B Late	30_{9}	90_{9}	$18_{8,9}$	0.7_{8}	—	—	$14_{8,9}$

[1] LD 50's are expressed in μg. insecticide per vial. Subscript numbers indicate generations tested in each case. For comparison with DDT, certain values from tables 1 and 2 are repeated in the second column.

4.15 (0.241); SL DDT 4.85 (0.206); B Check 2.16 (0.463); B Early 2.15 (0.465); B Late 2.55 (0.392); B DDT 2.57 (0.389). However, this is an unusual method for expressing slope, since it is the horizontal distance per unit rise instead of the rise per unit horizontal distance, i.e., the reciprocal of the figures given. The numbers in parentheses are the true slopes.

Dosage mortality tests were made also for the various substrains with DDD, methoxychlor, lindane, aldrin, dieldrin and pyrethrin concentrate. These were carried out in the same manner as with DDT, but included only one or two generations near the middle of the experimental period with the SL flies and at the end of the period with the B flies. The results in terms of LD 50's are given in table 3.

It is clear that DDD susceptibility varies in the same way as that of DDT in both strains but to a somewhat exaggerated degree in the SL Late substrain. Susceptibility to methoxychlor is much less affected and with the B flies all three substrains probably lay within the same range. Selection by length of larval period is not markedly successful with methoxychlor as toxicant and this method of selection did not alter the effects of the other four insecticides.

There is an indication in table 1 that the LD 50 for DDT with the SL Late substrain was declining near the end of the test period. This colony has been continued with selection at each generation to the present time. In June, 1953, with the thirty-eighth generation under selection the LD 50 was found to be 22 μg. per vial. In April, 1954, after 53 generations a careful redetermination of LD 50's for all seven insecticides gave the following results in μg. per vial:

DDT	*DDD*	*methoxychlor*	*lindane*	*aldrin*	*dieldrin*	*pyrethrins*
7	18	2.5	0.27	0.22	0.20	12

Comparison with the third line of table 3 shows that the LD 50's have decreased approximately 16:1 for the DDT family, 3:1 for lindane, about 2:1 for aldrin and dieldrin, but that for pyrethrins is unchanged within the certainty of the tests.

Coincidently, the oviposition to midpoint of pupation period decreased from about 260 hours, cf. table 1, to an average of 184 hours (53rd and 54th generations) and the pupation period (i.e., first to last pupa) from about 170 hours to an average of 84 hours. These periods are now about the same as those of the unselected check SL strain.

Discussion.—There is considerable inconsistency in the results reported in the literature on persistence of resistance to insecticides during the course of laboratory rearing of house flies. A typical example is the report by March & Metcalf (1950) that the highly resistant Bellflower strain was reared for over 35 generations without appreciable change in resistance, whereas Pimentel *et al.* (1953) found that their highly resistant strain A_1 after 20 generations free from insecticide had declined to one eight-hundredth of the initial level with females and twice as far with males. They used all pupae of each generation and collected eggs over a 5-day period, with the obvious purpose of eliminating the effects of early and late selection. If this was accomplished, then the rapid loss of resistance would seem to

be due to some factor favoring the susceptible portion of the population, such as greater oviposition by the more susceptible females, or greater hatchability of the eggs or higher survival of resulting larvae. In their earlier work Pimentel *et al.* (1951) found no such differences among strains of varying susceptibilities and the present work has not shown them to occur in the case of early and late strains of different susceptibilities. Recently Pratt & Babers (1953) have cited the case of the resistant strain R-BF which maintained its resistance through 35 generations reared at Orlando, Florida, but lost it in 10 generations at Beltsville, Maryland.

In nature even a very slightly shorter preoviposition period e.g., resulting from the shorter larval life of the more susceptible portion of the population, may be expected to result in an average high susceptibility, although highly resistant individuals will persist in small numbers. This is the reason why naturally highly resistant strains of the house fly do not occur. On the one hand, laboratory breeding as ordinarily carried on *by generations* permits either conscious or subconscious selection on the basis of length of the life cycle, and eliminates the higher reproduction potential resulting from a shorter larval period. On the other hand, unless special precautions are taken to include *all* individuals, those which are slow in coming to mating and oviposition may not be allowed to reproduce. It seems probable that many of the contradictory results regarding changes in susceptibility of laboratory strains of house flies may be traced to unrecognized differences in handling the larvae so that the breeding stocks were taken from slightly different cuts during the pupation period.

The present work supplies no reason why the length of the larval period should be correlated with the reaction to a toxicant, nor does it even indicate which is cause and which is effect. Various possibilities may be suggested, e.g., the more resistant individuals have a greater requirement for some vitamin, mineral, amino acid, etc., which is present in the food in very limited amount and hence they must eat longer to meet their need, or an enzyme involved in the defense against DDT, e.g., that which dehydrohalogenates the toxicant to DDE (Perry & Hoskins 1950, 1951), has adverse effects upon growth when present in relatively large amounts. Whatever the mechanism involved, it appears to have no relation to the toxic effects on lindane, aldrin, dieldrin or pyrethrins in the two strains studied. Such a relation might exist in strains made resistant to one of these chemicals by selective exposure.

The increase in tolerance for DDT and its close relatives which is associated with a long larval period reached a maximum after about 15 generations and then slowly declined, though selection of late pupae was carried on continuously. Such behavior would result from the interplay of two sets of biological factors, one coming to maximum development within a few generations and giving increased tolerance to only the DDT type of insecticide and the other requiring much longer to develop but ultimately having much more influence, so that tolerance falls to a low level. This change is accompanied by a shortening of the larval and the pupation periods which have become approximately equal to the corresponding intervals for the unselected check strain. A decrease in general vigor is not indicated to be the cause, for egg production, longevity and general activity are normal and tolerance for pyrethrins remains steady through the whole period.

SUMMARY.—A strain of house flies moderately resistant to DDT was split into an Early substrain and a Late substrain by successive selection of the first half to pupate into one colony and the latter half to pupate into a second colony. The period from oviposition to midpoint of pupation decreased slightly in the Early substrain and increased about 50 per cent in the Late substrain. The pupating periods from first to last pupation were altered similarly. Resistance of the adults decreased slightly in the Early substrain and increased six to eight fold in the late substrain after 15 generations. Changes in susceptibility to DDD were more marked than to DDT, but were slight to methoxychhlor and absent with lindane, aldrin, dieldrin and pyrethrins. Similar but numerically smaller changes occurred with a strain originally highly susceptible to DDT.

Further selection of the late pupae led to a slow decrease in resistance to the DDT type of insecticides, so that after 53 generations the flies were more susceptible

than an unselected check strain. The length of the oviposition to midpoint of pupation period simultaneously decreased approximately to that of the check strain. The susceptibility to pyrethrins was unchanged and to aldrin and dieldrin was cut about in half. General vigor, fertility and longevity were not affected. Selection of longfeeding larvae apparently accentuates two biological factors. One comes to a maximum in a few generations and leads to marked resistance to DDT and related compounds. The other comes on very slowly but ultimately overcomes the first and gives low resistance to the same insecticides. The effect of pyrethrins is unchanged through the whole period of selection. This work demonstrates that significant changes in resistance to DDT may result from selection of pupae without any exposure to a chemical, and illustrates how unexplained variations in susceptibility of laboratory colonies may come about.

LITERATURE CITED

Bruce, W. N. 1949. Latest report on fly control. Pest Control **17**(6): 7, 28.
Hoskins, W. M., and A. H. Caldwell. 1947. Development and use of a small spray chamber. Soap and Sanitary Chemicals **23**(4), 143–5, 161, 163, 165, 167.
Hoskins, W. M., J. M. Witt, and W. R. Erwin. 1951. Bioassay of 1,2,3,4,5,6-hexachlorocyclohexane (Lindane). Anal. Chem. **24**: 555–60.
Litchfield, J. T., Jr., and F. Wilcoxon. 1949. A simplified method of evaluating dose-effect experiments. Jour. Pharm. and Exper. Therap. **95**: 99–113.
March, R. B., and R. L. Metcalf. 1950. Insecticide-resistant flies. Soap and Sanitary Chemicals **26**(7): 121, 123, 125, 139.
March, R. B., and L. L. Lewellen. 1950. A comparison of DDT-resistant and non-resistant house flies. JOUR. ECON. ENT. **43**: 721–2.
Perry, A. S., and W. M. Hoskins. 1950. The detoxification of DDT by resistant house flies and inhibition of this process by piperonyl cyclonene. Science **111**: 600–1.
Perry, A. S., and W. M. Hoskins. 1951. Detoxification of DDT as a factor in the resistance of house flies. JOUR. ECON. ENT. **44**: 850–7.
Pimentel, D., J. E. Dewey and H. H. Schwardt. 1951. An increase in the duration of the life cycle of DDT-resistant strains of the house fly. JOUR. ECON. ENT. **44**: 477–81.
Pimentel, D., H. H. Schwardt, and J. E. Dewey. 1953. Development and loss of insecticide resistance in the house fly. JOUR. ECON. ENT. **46**: 295–8.
Pratt, J. J., and F. H. Babers. 1953. The resistance of insects to insecticides. Some differences between strains of house flies. JOUR. ECON. ENT. **46**: 864–73.
Tahori, A. S., and W. M. Hoskins. 1953. The absorption, distribution and metabolism of DDT in DDT-resistant house flies. JOUR. ECON. ENT. **46**: 302–6, 829–37.
Wiesmann, R. von. 1947. Untersuchungen über das physiologische Verhalten von *Musca domestica* L. verschiedener Provenienzen. Schweiz. Entom. Gesellsch. Mitt. **20**: 484–504.

Insecticide Tests with Cabbage Caterpillars and Aphids[1]

L. E. DILLS and M. L. ODLAND[2]

Several of the chlorinated compounds are much more effective against cabbage caterpillars than insecticides formerly recommended. This previously has been reported (Huckett 1946, Dills & Odland 1948, Reid & Cuthbert 1949). In prior tests it has been found that significant differences often are difficult to detect between the more effective materials when applied at usual concentrations. Relative effectiveness of compounds of similar toxicity has been found to be determined most easily through comparison of results at several reduced concentrations.

Since more information on comparative toxicity was desired in evaluating the chlorinated compounds for cabbage caterpillars, additional field tests were made in 1951, 1952, and 1953. These experiments were conducted in an area where few insecticides had been used; therefore, it seems unlikely that the insect populations had developed more than negligible resistance to any of the materials tested.

Several of the more effective compounds, including DDT, dieldrin and TDE, were used at much reduced concentrations in these tests. A number of

[1] Authorized for publication on May 4, 1954 as paper No. 1875 in the Journal Series of The Pennsylvania Agricultural Experiment Station.
[2] Associate Professor of Economic Entomology and Professor of Olericulture, respectively.

other materials that had not been used or needed further testing were included. These were allethrin, 1,1-bis (p-ethylphenol)-2,2-dichloroethane, chlordane, heptachlor, isodrin, lindane, methoxychlor and ryania.

METHODS.—As far as possible the materials were compared on an equal weight basis of actual toxicant. They were all applied as dusts and were prepared from wettable powders and dust concentrates. Pyrophyllite was the diluent used in 1951 and 1953 while attapulgite clay was used in 1952. Applications were made with a rotary type hand duster and all materials were administered as uniformly as possible.

In 1951 Penn State Ballhead cabbage plants were set in July and three applications of dust were made at 7- to10-day intervals during August. Frequent examinations for caterpillar injury were made. Although a few diamondback moth, *Plutella maculipennis* (Curt.), larvae were present most of the feeding damage was caused by the cabbage looper *Trichoplusia ni* (Hbn.) and the imported cabbage worm *Pieris rapae* (L.). These two species were about equally abundant and caused considerable damage in the untreated plots. The field work for 1951 was designed specifically to determine the effectiveness of insecticides on cabbage caterpillars but since hot dry weather favored the development of the cabbage aphid, *Brevicoryne brassicae* (L.), observations also were made on this insect.

Penn State Ballhead cabbage was again used in 1952 but unfortunately the plants were not set until very late summer. Three applications of dust were made during September. Due to the lateness of the season the infestation of caterpillars was low and many plants showed no injury. Counts indicated that most of the damage was caused by the cabbage looper but the imported cabbageworm and diamondback moth larvae were present and caused some injury. During 1952, a light infestation of aphids again occurred.

A planting of Golden Acre cabbage was used for the tests in 1953. Since this planting had been set for another purpose, considerable damage occurred before the first treatments could be made. Two insecticide applications were made a week apart in early July. Unfortunately, at the time of the first application, immediately after TDE and the two lower concentrations of isodrin had been applied, the work was interrupted by several days of rainy weather. These treatments were reapplied at the time the remaining treatments of the experiment were made. This application probably gave these two compounds a slight advantage. At the time the feeding rating was taken, counts showed that the infestation consisted of cabbage looper and the imported cabbageworm, the former being considerably more abundant. In 1953 aphid damage was negligible as had been anticipated because of cool wet weather, therefore lindane was not included in the tests.

Table 1.—Relative effectiveness of various insecticidal dusts against aphids and caterpillars on late cabbage, 1951.

INSECTICIDE	PER CENT CONCENTRATION	ADJUSTED AVERAGE		ADJUSTED YIELDS (TONS PER ACRE)
		Aphid Rating[1]	Feeding Rating[1]	
DDT	2	8.3	2.3	2.1
	1	7.4	3.5	1.8
	0.5	8.2	4.1	1.7
TDE	1	8.4	3.1	1.7
	0.5	8.8	3.2	1.3
1,1 Bis(p-ethyl phenyl)-2,2-dichloroethane	2	8.1	3.9	2.0
	1	7.7	4.5	2.1
Methoxychlor	2	8.0	4.7	1.7
	1	8.3	5.0	1.4
Allethrin	0.23	7.1	4.9	3.2
Ryania	15	7.5	3.5	3.4
Dieldrin	1	7.3	3.2	3.3
	0.5	7.4	3.6	2.3
Lindane	1	3.0	3.6	7.1
Chlordane	1	7.6	5.3	2.3
Untreated	—	8.0	6.8	1.1
L.S.D. at the 5% level		0.64	0.52	1.1

[1] Rating scale: 1=no injury; 2=very slight; 3=slight; 4=slight +; 5=moderate −; 6=moderate; 7=moderate +; 8=severe −; 9=severe; 10=very severe.

Plots were arranged in a triple lattice design in 1951 and 1953, while randomized complete blocks with six replications were used in 1952. In 1951 a plot consisted of three rows, each 27 feet long. The next year a plot was composed of two rows, each 37½ feet in length while in 1953 the plots were two rows, each 25½ feet or more in length. In order to eliminate as much as possible the drifting of the dusts to adjacent plots, buffer rows in 1951 and buffer areas in 1952 and 1953 were used on each side of the treated rows. Thirty plants per plot in 1951 and 1952 and an average of 29 plants per plot in 1953 were examined and rated for feeding injury on a scale of 1 to 10 (see footnote, Table 1).

Table 2.—Relative effectiveness of various insecticidal dusts against aphids and caterpillars on late cabbage, 1952.

Insecticide	Per Cent Concentration	Average Feeding Rating	Average Per Cent Plants Showing Aphid Injury	Sum of Equiv. Angles of Aphid Injury
DDT	0.50	1.5	31.7	204.7
	0.25	1.6	33.4	209.1
TDE	0.50	1.4	33.3	208.2
	0.25	1.5	27.8	188.9
Dieldrin	0.50	1.4	27.8	189.8
	0.25	1.9	18.9	140.9
Dieldrin+Lindane, 1%	0.50	1.1	5.6	65.3
Untreated	—	3.3	30.6	199.8
L.S.D. at the 5% level		0.32	—	63.1

Table 3.—Combined results of relative effectiveness of various insecticidal dusts against caterpillars on early cabbage, 1953.

Insecticide	Average Adjusted Feeding Rating
Isodrin	6.5
TDE	6.6
DDT	7.2
Dieldrin	7.5
Heptachlor	7.7
L.S.D. at the 5% level	0.14

Aphid injury was determined in the same manner in 1951 while in 1952 percentages of plants showing aphid damage in each plot was determined. Yields were taken only in 1951.

DISCUSSION.—A summary of results is given in the accompanying tables. Since the infestation of cabbage caterpillars was very light in 1952 and considerable feeding occurred in 1953 before an insecticide was applied, most of the reliance must be placed on the results obtained in 1951. Because of the high experimental error which occurred in 1953, it seems best to combine the results for that year instead of giving the average feeding rating associated with each treatment. The materials were used at 0.25, 0.5 and 1 per cent which are very reduced concentrations. All treatments with the exception of heptachlor at 0.25 per cent, which was the lowest concentration used, gave significantly better results than the untreated plots.

Use of TDE resulted in the least caterpillar damage of any of the insecticides which were tested for more than 1 year. In 1951 and 1953, when the results for the different concentrations were combined, TDE was found to be significantly better than DDT. TDE gave better results than dieldrin but only in 1953 was it significantly better. It should again be mentioned that TDE probably had a slight advantage over DDT and dieldrin in 1953, because an extra application was made after the first had been washed off by rain. Dieldrin was approximately equal to DDT and the results for 1952 indicate that there were no significant differences between these two materials. In 1951 dieldrin gave significantly better results than DDT while in 1953 the reverse was true. This apparent discrepancy could be due to experimental error or to slight variations in the concentrates used in preparing the dust; but, it seems more probable that it might be due to variations in the relative abundance of the different species of caterpillars and in variations in toxicity of these materials to them. It has been reported (Reid & Cuthbert 1949) that several of the chlorinated insecticides vary in their relative toxicity to the different species of cabbage caterpillars.

Isodrin was used only in 1953 and the results indicate that for the caterpillars present it was equal in toxicity to TDE. Heptachlor also was used only in that year and feeding ratings indicated that it is less toxic to these caterpillars than isodrin, TDE, DDT, or dieldrin.

One per cent lindane and 15 per cent ryania with 0.5 per cent n-propyl isome as a synergist were found in 1951 to be moderately toxic to cabbage caterpillars. The results for the same year showed, 1,1 bis(p-ethylphenol)-2,2-dichloroethane superior to methoxychlor in preventing injury. Although these two materials were much less toxic to these insects than some of the other chlorinated compounds, they have the advantage of possessing a comparative low toxicity to higher animals. The concentration needed to obtain satisfactory control of cabbage caterpillars with these materials was not determined. Allethrin at 0.23 per cent with 0.2 per cent N-2-ethylhexylbicyclo 2.2.1-5-heptene-2, 3-dicarboximide as a synergist also failed to give satisfactory results. As would be expected from previous work (Dills & Odland 1948, 1950), chlordane at one per

cent was ineffective in 1951 and with the exception of methoxychlor it was significantly inferior to the other chlorinated compounds tested.

In 1951 no very pronounced reduction in aphid infestation was found due to any of the treatments except lindane at 1 per cent. The toxicity of this material to cabbage aphids has previously been reported (Friend 1946, Greaves & Venables 1948, Hervey 1946, Reid & Cuthbert 1949, Wene & White 1952). Dieldrin at 1 per cent and allethrin were the only other treatments for that year which showed a significant reduction in aphid damage. Much of the reduction in yield for that year was due to hot dry weather but the remainder was due largely to aphid damage. Since lindane was most effective in aphid control, the plots treated with it gave the highest yields. In 1952 lindane combined with dieldrin also was effective in reducing aphid injury. For that year, this was the only treatment which showed a significant reduction in infestation.

LITERATURE CITED

Dills, L. E., and M. L. Odland. 1948. Cabbage caterpillar insecticide tests. JOUR. ECON. ENT. **41**(6): 948–50.

Dills, L. E., and M. L. Odland. 1950. Insecticide tests with cabbage caterpillars. JOUR. ECON. ENT. **43**(3): 384–5.

Friend, A. H. 1946. Cauliflower seed crop pests. Field experiments with the newer insecticides. Observations and results. Agric. Gaz. N. S. Wales. **57**(4): 181–2.

Greaves, T., and D. G. Venables. 1948. The insecticidal control of cabbage pests: A summary of experimental results 1944–48. Jour. Coun. Sci. Ind. Res. (Australia) **21**(3): 171–6.

Hervey, G. E. R. 1946. Effect of various dust mixtures on incidence of the cabbage aphid. JOUR. ECON. ENT. **39**(2): 265.

Huckett, H. C. 1946. DDT and other new insecticides for control of cauliflower worms on Long Island. JOUR. ECON. ENT. **39**(2): 184–8.

Reid, W. J., Jr., and F. P. Cuthbert, Jr. 1949. Field-plot comparisons of DDT and other new materials for control of caterpillars on cabbage. U. S. Bur. Ent. and Plant Quar. **E-787.**

Wene, George P., and A. N. White. 1952. Toxicity of new insecticides to cabbage aphids. JOUR. ECON. ENT. **45**(1): 118–20.

The Frequency of Multiple Mating of Queen Honey Bees

STEPHEN TABER, III, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*[1]

The mating habits of queen honey bees, *Apis mellifera* L., have been studied extensively since Huber (1814) described the mating sign and noted that two queens returned with the mating sign twice. Most of the early work generally confirms Huber's observation that if a queen mates twice the first mating must have been poor or inconsequential. Reviews of the early work have been given by Nolan (1932) and Betts (1939). More recently Roberts (1944), observing flights of a large number of virgin queens, found 50 per cent of them returned with mating signs twice, and indicated that ". . . all desired flights may not have been permitted." Roberts' mating station tests on free-flying queens indicated that more than 50 per cent of his queens were mating more than once. Triasko (1951) used a different method. He dissected queens returning from a mating flight in order to compare the volume of sperm in the queen's oviducts with that in the seminal vesicles of a drone. From this comparison he estimated that each queen had mated with four or five drones. He speculated that each drone removed the previous mating sign and left his own.

Early observers considered the mating sign to be evidence of complete mating. whether or not sperm was received in the spermatheca of the queen. The results given here answer the following questions: (1) Is there always sperm in the spermatheca when a queen returns from a flight

[1] In cooperation with Louisiana State University, Baton Rouge.

with a mating sign? (2) Is there sperm in the spermatheca if the queen returns from a flight with no mating sign? (3) Do queens mate more than once on a single flight? This study was undertaken because some casual observations made in 1951 indicated that a larger proportion of queens were mating with more than one drone than had heretofore been believed.

GENERAL METHOD.—Extensive use of a recessive genetic mutation, cordovan, was made in determing the number of matings taking place. The effect of the mutation is to change the body color of all homozygous mutant individuals. Data from controlled matings are presented schematically to illustrate the genetic action of the mutant, termed "c."

PARENTS	PROGENY			
Dam Sire	Female (Diploid)		Male (Haploid)	
cc×C	Cc		c	
cc×c	cc		c	
Cc×c	½ Cc	½ cc	½ C	½ c
Cc×C	½ CC	½ Cc	½ C	½ c
CC×c	Cc		C	
CC×C	CC		C	

If virgin mutant queens (cc) are mated to normal drones (C), all female offspring are normal. If mutant queens (cc) are mated to mutant drones (c), all female offspring are mutant. If mutant virgins (cc) are inseminated with both kinds of sperm, both normal and mutant female progeny appear.

Virgin mutant queens flew from hives in an apiary stocked with drones, about half of which were mutant and half were normal. The location was not isolated, and we do not know how far a queen will fly in search of a drone. Furthermore, drones carrying the mutant gene may be weaker than those carrying the normal gene. These sources of variation should make little difference in the accuracy of the experiment, as we can determine the most probable drone population by fitting the best theoretical curve to the accumulated data.

There are three possible classes of queens, according to their progeny: (1) Progeny all normal, (2) progeny all mutant, and (3) progeny of both kinds. Classes (1) and (2) include queeens that mate with 1, 2, . . . n drones, either all normal or all mutant. Class (3) includes queens that mate with at least 2 drones, normal and mutant, or with 1 normal+ n-1 mutant, 2 normal+n-2 mutant, . . . n-2 normal+2 mutant, n-1 normal+1 mutant. The mathematical expression of these classes is the binomial $(p+q)^n=1$, where p = the probability of mating with a normal drone, q = the probability of mating with a mutant drone, and n = the number of matings per queen.

The possibility of a biased experiment because of the stock used is remote. The colonies in the apiary were headed by queens procured from a number of independent commercial sources. The mutant gene was introduced by natural matings only, with outcrossing through more than 10 generations.

TESTS WITH FREE-FLIGHT QUEENS.—Several hundred marked virgin mutant queens were allowed to fly from the apiary having unknown populations of normal and mutant drones. The identity of each queen and her progeny was ascertained before inclusion in the experiment, and mutant or normal progeny in excess of 1 per cent was deemed necessary because of the possibility of parthenogenetic female eggs from workers or queen.

Data collected in 1952 from 184 queens allowed free flight are as follows:

NUMBER OF QUEENS	PROGENY	RELATIVE FREQUENCY
171	Normal and mutant	0.92935
13	Normal only	.07065
0	Mutant only	.00000

Since 13 queens produced all normal and none produced all mutant progeny, it seems likely that there existed a larger proportion of normal than mutant drones. The closest figure is a population of $\frac{1}{3}$ mutant and $\frac{2}{3}$ normal drones and queens mating an average of 6.5 times to give the following expectations:

EXPECTED NUMBER OF QUEENS	PROGENY	EXPECTED FREQUENCY
170.68	Normal and mutant	0.9276
13.17	Normal only	.0716
.15	Mutant only	.0008

CONCLUSIONS.—The data presented indicate that queen honey bees allowed free flight mate on an average $6\frac{1}{2}$ times. Virgin queens allowed only one flight indicate a large proportion of multiple matings on a single flight. The presence of the mating sign is not a reliable index to the presence of sperm in the spermatheca.

It seems likely that the actual number of matings must be not less than four and not more than nine. The standard deviation (s) of the number of matings per queen where $n=6.5$, $p=\frac{1}{3}$, and $q=\frac{2}{3}$ is $\sqrt{npq}$ or 1.2.

Progeny counts of 12 free-flight queens, together with the percentage of normal progeny, are presented in table 1. The variation in these percentages is due, in part at least, to unequal amounts of sperm in the spermatheca.

If queens mate on an average $6\frac{1}{2}$ times, then it becomes necessary to show that a large number of queens mate more than once on one flight.

SINGLE OBSERVED FLIGHT.—After emerging from the queen cell, virgins were given a distinctive mark on the thorax for identification and a queen-excluder zinc was placed at the entrance of each nucleous to prevent flight. The method of observation of flights was similar to that described by Oertel (1940) and Roberts (1944), except that excluders were removed and a continuous watch was kept for appearance of the queen at the entrance. Virgin mutant queens were allowed to make one flight. The time and duration of flight and the presence or absence of the so-called mating sign were then noted. When the queen returned from her flight, her wing was clipped to prevent any future flight. All queens that failed to lay or that laid infertile eggs had their spermathecae examined in about 2 weeks. Queens that laid fertile eggs had their progeny examined 3 weeks after beginning egg deposition. Queens that produced either all normal or all mutant offspring had their progeny checked for evidence of multiple matings several times during the first 10 days of emergence.

Sperm were counted as described by Mackensen & Roberts (1948), with the aid of a haemocytometer. Laying queens not included in the data were eliminated early in the egg-laying period, before any progeny had emerged.

Data collected in 1953 from 39 mated queens that flew once and laid fertile eggs are as folows:

NUMBER OF QUEENS	PROGENY	RELATIVE FREQUENCY
34	Mutant and normal	0.8718
1	All normal	.0256
4	All mutant	.1026

Clearly this indicates that a large number, probably all, of the queens that mated, mated more than once on one flight. Data on the flight time, presence of the mating sign and sperm count of each of these queens are presented in table 2. The average flight time for the 39 mated queens was 13 minutes (3:09–3:22 P.M.); and for 63 non-mated queens 8 minutes (2:51–2:59 P.M.). This compares with flight data reported by Roberts (1944).

Thirty-six queens were available for sperm counts after their progeny test. The average number of sperms was 3.27 million, as compared with 5.73 million from 33 naturally mated queens reported by Mackensen & Roberts (1948). It would be expected that single-flight mated queens would have less sperm than those allowed free, or multiple, flights.

Three queens returned with the mating sign, but when examined 2 weeks later there was no sperm in the spermatheca. Two queens had a small thread (possibly Triasko's "mucus tail") protruding from the abdominal plates; one of these (No. 106) contained sperm, but the other did not. Three queens (Nos. 28, 65, 111) returned with no mating sign but were

Table 1.—Progeny counts of 12 queens naturally mated in 1952.

QUEEN	TOTAL BEES COUNTED	PER CENT NORMAL
T2-1	6,667	87
J2-7	4,109	81
T2-4	4,161	59
H2-1	7,376	97
C5-1	9,924	76
T2-5	7,764	65
D3-1	7,951	75
D3-2	7,923	76
J1-1	10,092	95
OR-1	12,113	78
T2-2	15,364	63
C5-2	15,832	90

Table 2.—Data on queens that made one flight between May 19 and June 10, 1953, showing flight time, mating sign, type of progeny and sperm count.

Queen No.	Time Cut	Time In	Presence or Absence of Mating Sign	Progeny	Sperm Count in Millions
	p.m.				
26[1]	2:16	2:30	+	mixed	1.53
28[1]	2:20	2:38	−	mixed	1.44
31[1]	2:41	2:58	+	mixed	
50[1]	3:27	3:40	+	mixed	3.54
37[1]	2:10	2:27	+	mixed	1.69
57	2:31	2:40	+	mixed	4.69
60	3:14	3:30	+	mixed	3.30
61[1]	3:29	3:50	+	all cord	3.94
62[1]	3:37	3:49	+	mixed	.93
63	2:57	3:09	+	mixed	2.91
64	3:48	4:01	+	mixed	3.45
65	3:50	4:00	−	mixed	3.41
66[1]	3:53	4:07	+	mixed	3.66
68[1]	?	3:01	+	mixed	3.79
72[1]	2:30	2:40	+	mixed	1.58
74[1]	3:05	3:21	+	mixed	2.84
75[1]	3:31	3:45	+	mixed	3.76
82[1]	2:47	3:02	+	all cord	3.85
86[1]	3:55	4:05	+	mixed	3.36
90	2:55	3:08	+	mixed	4.80
95	2:55	3:05	+	all cord	1.51
96	3:09	3:22	+	mixed	4.58
98	3:24	3:39	+	mixed	3.33
99	3:09	3:17	+	mixed	2.20
101	3:23	3:34	+	mixed	
102	3:52	3:58	+	mixed	2.10
104	4:25	4:36	?	mixed	2.90
106	4:38	4:50	+	mixed	3.16
111	2:30	2:45	−	all cord	2.49
112	2:44	2:58	+	mixed	4.63
113	3:02	3:16	+	mixed	3.78
116	3:38	3:55	+	mixed	1.11
119	2:48	3:02	+	mixed	4.34
120	2:49	2:58	+	mixed	3.78
122	3:15	3:27	+	mixed	
123	3:17	3:27	+	mixed	5.44
124	3:24	3:31	+	mixed	5.69
125	3:43	3:58	+	all normal	3.73
126	2:38	2:58	+	mixed	4.55
Average	3:09	3:22			3.27

[1] These queens were treated with carbon dioxide to induce egg laying.

mated as evidenced by the production of fertile eggs and the presence of sperm in the spermatheca. Therefore, a perfect correlation cannot be assumed to exist between the presence of the mating sign and the presence of sperm in the spermatheca.

DISCUSSION.—The most obvious criticism of these data is that a genetic mutation was used as the subject for a quantitative study of this kind, even though several breeder queens were used in the course of the experiment. Sexual behavior of the mutant may possibly be dissimilar to their normal counterpart, though there does not appear to be any particular evidence of that in these data.

Other observations indicate that the distribution of matings per queen may not be normal—that is, there may not be as many queens mating with 6 drones as with 7, or 5 as with 8, or 4 as with 9. There is no reason why a queen could not mate 4 times per flight and fly as many as 5 times—20 matings. Observations by Oertel (1940) and by Roberts (1944) indicate from 1 to 5 flights per queen and that all desired flights may not have been permitted.

In our observations 40 per cent of the queens mated on their first flight. There are probably a number of reasons why the others did not mate. It seems reasonable to suppose that differences would exist in mating habits of queens from different strains of bees or in different geographic locations.

Essentially the data in this paper confirm most other work, especially that of Triasko (1951).

LITERATURE CITED

Betts, A. D. 1939. The mating flight: a summary of present knowledge. Bee World **20**: 33–6.

Huber, F. 1814. New observations upon bees. 230 pp. Translated by C. P. Dadant, 1926. Hamilton, Ill.

Mackensen, O., and W. C. Roberts. 1948. A manual for the artificial insemination of queen bees. U. S. Bur. Ent. and Plant Quar. **ET-250.**

Nolan, W. J. 1932. Multiple matings of the queen bee. Md. State Beekeepers' Assoc., Rpt. **23rd** Annual Meeting, pp. 20–34.

Oertel, E. 1940. Mating flights of queen bees. Gleanings Bee Culture **68**: 292–3, 333.

Roberts, W. C. 1944. Multiple mating of queen bees proved by progeny and flight tests. Gleanings Bee Culture **72**: 255–9, 303.

Triasko, V. V. 1951. Signs indicating the mating of queens. Pchelovodstvo **11**: 25–31. In Russian, abstract by M. Simpson in Bee World **34**: 14.

House Fly Control in Dairies Near Savannah, Georgia, with Residual Applications of CS-708, NPD, and Malathion[1]

JOHN W. KILPATRICK and H. F. SCHOOF

To cope with the resistance problem in house fly control, much effort has been expended in recent years on the development of new insecticides or synergists for the currently available toxicants (March, *et al.* 1952, Perry & Hoskins 1951, Summerford *et al.* 1951). The obvious ability of *Musca domestica* to become resistant to the various chlorinated hydrocarbons and even to synergized insecticides has focused attention upon the organophosphorus compounds. While the latter generally are more toxic to both flies and humans than the chlorinated hydrocarbons, their chief value lies in the apparent inability of *M. domestica* to acquire resistance to them. On this basis, studies were undertaken to test the residual effectiveness of two organophosphorus compounds, NPD (tetra-n-propyldithionopyrophosphate), and malathion formulations in house fly control. Both of these compounds exhibit a much lower acute toxicity hazard to mammals than does parathion.[2] A DDT-synergized CS-708 formulation also was included in these tests.

METHODS.—All tests were conducted in dairies in the Savannah, Georgia, area, each establishment possessing a herd of 100 to 300 animals. The insecticide was applied to the interior surfaces of the milking barns, calf pens, and other animal shelters on each premises. Treatment was made at 100 lbs. pressure with a power sprayer equipped with a flat spray nozzle.

NPD was formulated at 2.5 per cent strength either as a suspension or an emulsion. Tests with malathion included 2.5 and 5.0 per cent emulsions with a sugar additive of 12 per cent, and also a 2.5 per cent suspension. Two CS-708 formulations were used, 5 per cent CS-708:2 per cent cottonseed oil, and 5 per cent CS-708:5 per cent DDT:2 per cent cotton seed oil.

Appraisal of the efficiency of the treatments was made by weekly grill counts (Scudder 1947) of house flies at each dairy. One untreated dairy served for check purposes.

RESULTS.—In 1952, treatment of three barns in late fall with NPD residues at dosages of 100 mg./sq.ft. produced promising result against resistant house flies. In 1953, two dairies were treated with NPD emulsions (100 mg./sq.ft.) and one with an NPD suspension at the same dosage. After treatment, the house fly populations at the three dairies declined to levels of approximately 15 flies per grill count (Figure 1). Such low indices persisted for a

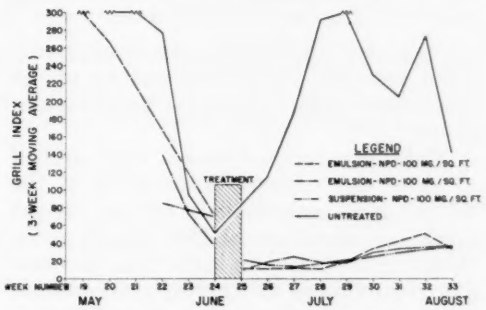


FIG. 1.—Fly densities at NPD-treated dairies.

period of 4 to 5 weeks. In contrast, fly population indices in the untreated dairy increased sharply to levels of 100 to 360 flies during the same time interval. Subsequent densities at the treated dairies indicated gradually rising fly counts to indices above 25 flies.

Data from the two dairies treated with CS-708 formulations indicated excellent house fly control (Figure 2), as the house fly prevalence levels were maintained at less than 12 flies per grill count throughout the entire 8-week period. Little difference was apparent in the effectiveness of the CS-708:cottonseed oil (200:80 mg./sq.ft.) and the CS-708:DDT:cottonseed oil (200:200:80 mg./sq.ft.) formulations. These findings are not consistent with laboratory studies which showed the CS-708 cottonseed oil to possess only minimal residual toxicity.[3] The lower fly potential present at the dairy barn re-

[1] From the Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Savannah, Ga.

[2] Unpublished data: Based on tests with female white rats, the acute dermal toxicity dosage for malathion and NPD in terms of LD-50 is approximately 295 and 165 times higher, respectively; than that for parathion.

[3] Unpublished data.

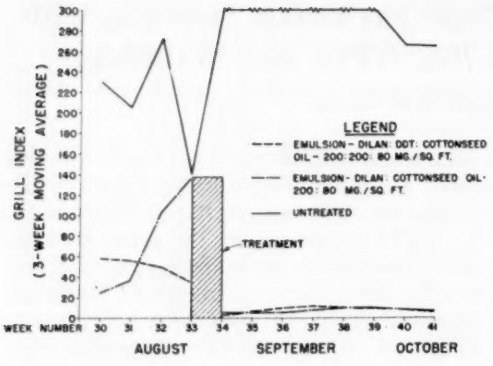

GRILL INDEX
(3-WEEK MOVING AVERAGE)
LEGEND
EMULSION - DILAN: DDT: COTTONSEED OIL - 200: 200: 80 MG./SQ. FT.
EMULSION - DILAN: COTTONSEED OIL - 200: 80 MG./SQ. FT.
UNTREATED
TREATMENT
WEEK NUMBER 30 31 32 33 34 35 36 37 38 39 40 41
AUGUST
SEPTEMBER
OCTOBER

FIG. 2.—Fly densities at CS-708-treated dairies.

ceiving the CS-708-cottonseed oil treatment provides partial explanation of the similarity in results with the two formulations.

Malathion residual sprays were applied at three dairy barns. Application of the 2.5 per cent malathion-12 per cent sugar emulsions at a rate of 100 mg. of malathion/sq.ft. caused an immediate spectacular reduction of the house fly population to an average of one fly per grill count. Subsequent indices remained below 18 flies per grill count for 2 to 4 weeks but a steady increase in numbers was apparent after the initial week.

Data from a second dairy treated with a 5 per cent malathion-12 per cent sugar emulsion (200 mg./sq. ft.) also revealed a marked reduction in fly densities, excellent control being apparent for 5 weeks. However, the onset of cool fall weather during the test period may have been a factor in prolonging the effectiveness up to 5 weeks.

The third dairy which received a treatment of malathion suspension at a rate of 100 mg./sq.ft. showed an immediate drop in fly densities to an index of 26 flies per grill count (Figure 3). Within 1 week after treatment, fly populations began to increase and continued to increase for the following 5 weeks. At this point flies were observed to be congregating and resting in the untreated feed room. Installation of malathion-impregnated cotton cords, $\frac{3}{16}$ inch diameter, in the feed room resulted in an estimated 25 to 50 per cent reduction of the fly population therein. On October 7, 7 weeks after the initial treatment, the feed room was sprayed with malathion suspension (100 mg./sq. ft.). Reduction of dairy fly populations to control levels of 10 flies per grill count was then obtained. Two weeks later low temperatures prevented further evaluation of the test.

DISCUSSION.—The CS-708 formulations offer definite promise as a residual agent in fly control. Although CS-708 emulsions generally have not been as effective as CS-708 suspensions against *Musca domestica*, the addition of the cottonseed oil alone or with DDT to the formulation apparently produces a fortified superior emulsion. Further field tests are required to define the relative values of the nondrying oil and the DDT in the emulsion.

Malathion produced a spectacular type of fly reduction upon application but the duration of its residual effectiveness was erratic. From wall cage tests at the dairies treated with emulsions, it was shown that malathion residues on painted surfaces lost their toxicity to flies after 1 week whereas deposits on unpainted surfaces continuted to be effective for 8 weeks.

From the present data, malathion with a sugar additive is highly effective against resistant house flies for short-term periods of 1 to 3 weeks. The relatively poor results with the 2.5 per cent malathion suspension and the probable effect of weather upon the extended efficacy of the 5 per cent malathion emulsion justify this viewpoint.

NPD was inferior to CS-708 as a residual treatment, but produced levels of fly control similar to those achieved with malathion. In view of their relatively low orders of mammalian toxicity, both of these organophosphorus compounds are suitable for use as short-term residuals in fly control.

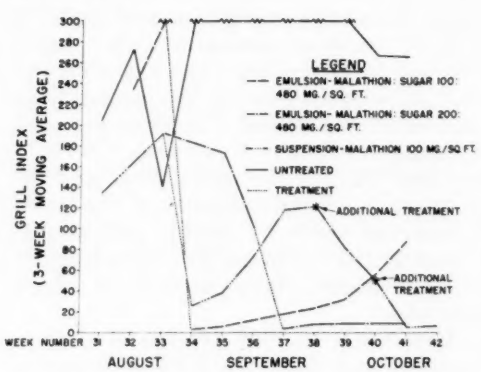


FIG. 3.—Fly densities at malathion-treated dairies.

SUMMARY.—Residual deposits of CS-708, NPD, and malathion were evaluated for their effectiveness in controlling resistant house flies in dairies near Savannah, Georgia. CS-708:cottonseed oil and CS-708:DDT:cottonseed oil emulsions applied at rates of 200:80 mg./sq. ft. and 200:200:80 mg./sq.ft., respectively, provided 8 weeks of excellent fly control. Treatments with emulsions of 2.5 and 5.0 per cent malathion plus a 12 per cent sugar additive gave good fly control for periods of 1 to 3 weeks. A malathion suspension (2.5 per cent) produced good control for 1 week. Wall cage tests indicated acute specificity as to the residual toxicity of malathion emulsion residues upon painted and unpainted surfaces. Applications of NPD formulations were about equal in effectiveness to malathion treatments but showed less residual toxicity than the CS-708 residues.

LITERATURE CITED

March, Ralph, B., R. L. Metcalf, and L. L. Lewallen. 1952. Synergists of DDT against insecticide resistant house flies. JOUR. ECON. ENT. **45**: 851–60.

Perry, A. S., and W. M. Hoskins. 1951. Synergistic action with DDT toward resistant house flies. JOUR. ECON. ENT. **44**: 850–7.

Scudder, H. I. 1947. A new technique for sampling the density of house fly populations. Pub. Health Rpts. **62**(19): 681–6.

Summerford, W. T., M. B. Goette, K. D. Quarterman, and S. L. Schenck. 1951. The potentiation of DDT against resistant house flies by several structurally related compounds. Science **114**: 6–7.

The Tomato Russet Mite in the United States[1]

LAUREN D. ANDERSON, *University of California Citrus Experiment Station, Riverside*[2]

The tomato russet mite, *Vasates lycopersici* (Massee), was first found in the United States at Modesto, California in 1940 by S. F. Bailey (Bailey & Keifer 1943). Since 1940 it has spread rapidly throughout the state and has become one of the most important pests of tomatoes (*Lycopersicon esculentum* Mill.) in California. It has spread through most of the southwestern states and during the last 2 to 3 years has appeared in damaging numbers in many of the north central and eastern states. In view of these facts it seems appropriate to review the status of this mite at this time.

SYNONYMY.—Since the scientific name of this Eriophyidae mite has recently been changed from *Vasates destructor* (Keif.) to *V. lycopersici* (Massee) by K. P. Lamb (1953), it seems advisable to review the synonymy of this pest.

Apparently, this mite was first reported as a pest on tomato in Queensland by Tryon (1916). Although he gave the name *Phyllocoptes lycopersici* for this mite, he did not give a description; the name is therefore not valid (*nomen nudum*). This matter was corrected by A. M. Massee (1937) when he published a description and assigned the name of *Phyllocoptes lycopersici* to this mite.

As stated by Lamb (1953) in his revision of the gall mites occurring on tomato, the description given by Massee was rather brief and was based on specimens preserved in spirits. This is probably the reason for its being redescribed by Keifer (1940) as a new species, *Phyllocoptes destructor*, on tomatoes in California. At a later date Keifer (1946) revised the *Phyllocoptes* genus, and placed *P. destructor* in another genus, *Vasates*. Lamb (1953) has compared descriptions and fresh specimens of mites from the type localities of *V. destructor* (Keifer) and *V. lycopersici* (Massee) and finds that they agree closely enough to be regarded as one and the same species. Thus, he gives the correct name as *Vasates lycopersici* (Massee). Keifer, in correspondence and in personal interview in December, 1953, stated that *V. lycopersici* (Massee) is undoubtedly correct since world-wide investigations reveal but one species of this type on tomato.

[1] Invitational paper presented at the meeting of the Entomological Society of America at Los Angeles, California, December 7–10, 1953.

[2] Acknowledgment is made to H. H. Keifer of the California State Department of Agriculture, Sacramento, A. E. Michelbacher of the University of California at Berkeley, and to S. F. Bailey of the University of California at Davis for information and assistance in preparation of this paper; to Kelvin Dorward of the United States Department of Agriculture and to the various entomologists in the 48 states who contributed information on distribution and control of the tomato russet mite.

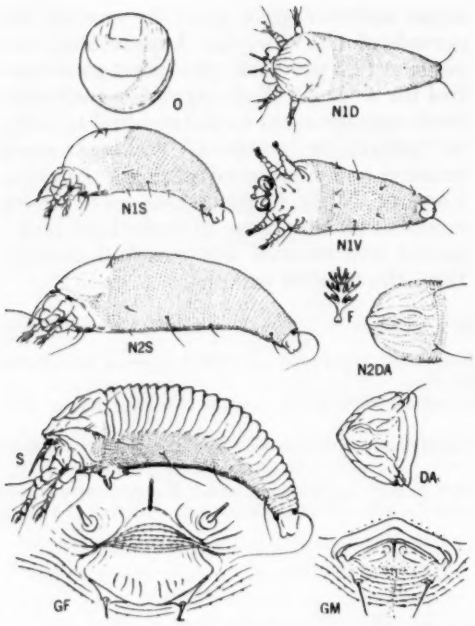


FIG. 1.—Tomato russet mite, *Vasates lycopersici* (Massee). Egg (0). First-stage nymph: dorsal view (N1D), side view (N1S), ventral view (N1V). Second-stage nymph: side view (N2S), cephalothoracic shield (N2DA). Adult: feather claw from below (F), side view of female (S), cephalothoracic shield (DA), female genitalia (GF), male genitalia (GM). (Camera-lucida drawings by H. H. Keifer.)

TAXONOMIC POSITION AND DESCRIPTION.—This eriophyid mite, which belongs to the subfamily Phyllocoptinae, may be differentiated readily from other eriophyid mites by the following set of characters: 2 shield setae, abdomen fusiform (not wormlike), with the dorsal half-rings (tergites) usually broader and fewer than the ventral half-rings (sternites); shield setae arising from the rear of the cephalothoracic shield margin and pointing backwards (except in first-instar larvae); the abdomen evenly rounded above and below (not with longitudinal ridges and furrows as with some species); the feather claw with 4 rays, the shield not projecting anteriorly into a definite frontal lobe but declivitous, the admedian line of the shield pattern forming a central elliptical figure. (For further details of characters, see Fig. 1.)

The tomato erinium mite, *Aceria lycopersici* (Massee), is another eriophyid that occurs on tomato in many parts of the world, but it has been recorded only from Florida (Rolfs 1907, Watson & Tissot 1942) in the United States. The erinium mite causes abnormal hairs to appear on leaves and stems of the tomato plant and gives it a grayish-whitish appearance. The russet mite, as the name implies, causes a russeting or browning of the affected part of the plant. The erinium mite belongs to the subfamily Eriophyinae and is characterized by having the abdomen wormlike, with rings similar above and below. The russet mite, as stated above, belongs to the subfamily Phyllocoptinae and has a fusiform body, with rings more abundant and narrower on the ventral side of the abdomen than on the dorsal side. For studying the taxonomic characters of these mites, a magnification of several hundred times is necessary, and an oil immersion objective is necessary for examining the feather claw. The mites must be properly prepared before they can be studied microscopically. For information on methods and formulas for preparing these mites, consult Keifer (1952).

ADULT.—The tomato russet mite is orange in color and is 150 to 200 microns long and about 55 microns thick when full grown. There are clinging lobes and hairs located on the posterior end of the body, and the genital openings are situated just behind the coxae. In the laboratory there is approximately a 2-day preoviposition period, and a female may lay up to at least 15 eggs. This mite is arrhenotokous; that is, unfertilized eggs develop into males only, which usually develop fast enough to mate with the mother and produce a normal bisexual generation. Bailey & Keifer (1943) found sex ratio to be about 60 per cent males to 40 per cent females.

EGG.—The eggs are large (55 microns in diameter) in comparison to the size of the female. They are opalescent-white, later becoming cloudy and yellowish, and they have a cap. The egg stage at room temperatures is about 2 days.

NYMPH.—The first-instar nymph is 90 to 100 microns long, is translucent white, and has a large beak (same size as in the adult). There are two pairs of cephalothoracic legs. In this instar there are genital setae but no genital organs. The setae on the shield point upward and forward and there are no adbominal dorsal rings or microtubercles just behind the setae. Only 1 day is spent in the first instar.

The second-instar nymph is 140 to 160 microns long and is more yellowish than the first-instar and the setae on the shield point backwards. Rings and microtubercles are present on the abdomen, also genital setae but no genital organs. Two days are spent in the second instar.

Although the egg-laying rate of this mite may not be unusually great, its short life cycle (7 days or less) and its arrhenotokous habit give it a high biotic potential, which has been verified frequently by observations of rapid increases of this pest in tomato fields.

HOSTS.—This mite has been recorded as developing on various solanaceous plants including tomato, potato, petunia, *Datura ferox* L. (Chinese thorn apple), *Datura stramonium* L. (jimson weed), three nightshades, *Solanum nigrum* L. (black nightshade), *S. nodiflorum* Jacq. (small-flowered nightshade), and *S. villosum* Lam. (hairy nightshade). It also developes on *Physalis ixocarpa* Brot. (ground cherry) and possibly some hosts other than solanaceous plants. Keifer points out the fact that this mite has the so-called "Solanum stimulation" character for tomato, like that of the Colorado potato beetle and the potato tuberworm for the potato. That is to say, these mites are so fond of and so destructive to this specific host that they kill it; thus they must have some other host on which they are less destructive and therefore are able to continue the perpetuation of the species. In California this alternate host may be petunia.

INJURY AND HABITS.—This mite may appear near the top of the plant, but usually appears first on the stalks near the ground and spreads upward on the stems and to the leaves. Surface-feeding causes a bronzed or russeted appearance. The stalks crack or check in 3 to 4 weeks, and the leaves turn brown and paperlike, but do not wilt as is the case with some diseases. Injured leaves may drop from the plants, even before turning brown. The loss of foliage may result in sunburned fruit. Only in the severest infestations does the fruit become russeted. The mites are spread rapidly at picking time, this condition indicating transportation on boxes, pickers, etc. Although they may be dispersed by wind, this method is not the main cause of rapid spread within a given field. As the host plants are drying and becoming unattractive to the mites, they migrate to the top of the plant and wave back and forth as if trying to attach to some passing object. They will actually jump off into space. Differing from most eriophyids, these mites resist sunlight and are able to feed on open surfaces of the foliage in direct sunlight. The russet mite is a warm-weather-loving mite without a dormant season, and is therefore unable to survive in areas where cold weather kills its host plants. If exposed to subfreezing temperature all stages of the mites die within a few hours to a few days. They can live about 4 days without food in the summer time. In California overwintering hosts, particularly petunias, are available in protected places in practically all tomato-growing areas. Cold frames and greenhouses are also a source of overwinter survival. Undoubtedly, this mite is able to survive the winter outdoors all across the southern part of the United States and in greenhouses in the northern states.

Predaceous mites, *Typhlodromus* spp., may help keep this pest under control in gardens. Also a thrips, *Leptothrips mali* (Fitch), feeds on the tomato russet mite.

DISTRIBUTION.—As stated above, this mite was first found in California in 1940 in a greenhouse in Modesto. Since it spread over the entire tomato-producing area in California in 2 years, it is doubtful if it had arrived in California much before 1940. Its original habitat may be Australia, but its mode of entry into California is unknown.

In 1952 the author received letters from J. M. Wright of Illinois, Ray L. Janes of Michigan, and H. E. Dorst and G. F. Knowlton of Utah asking for information on importance and control of this mite and stating that it was a problem in their respective areas. A letter (October, 1953) from Kelvin Dorward, of the Economic Insect Detection and Reporting Section, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, reports the tomato russet mite in 1952 in California, Illinois, Massachusetts, Michigan, New Jersey, Ohio, Pennsylvania, and Texas; and in 1953 in California, Delaware, Georgia, Illinois, Indiana, Iowa, Maryland, Michigan, New Jersey, Pennsylvania, and Utah.

An inquiry in regard to the distribution

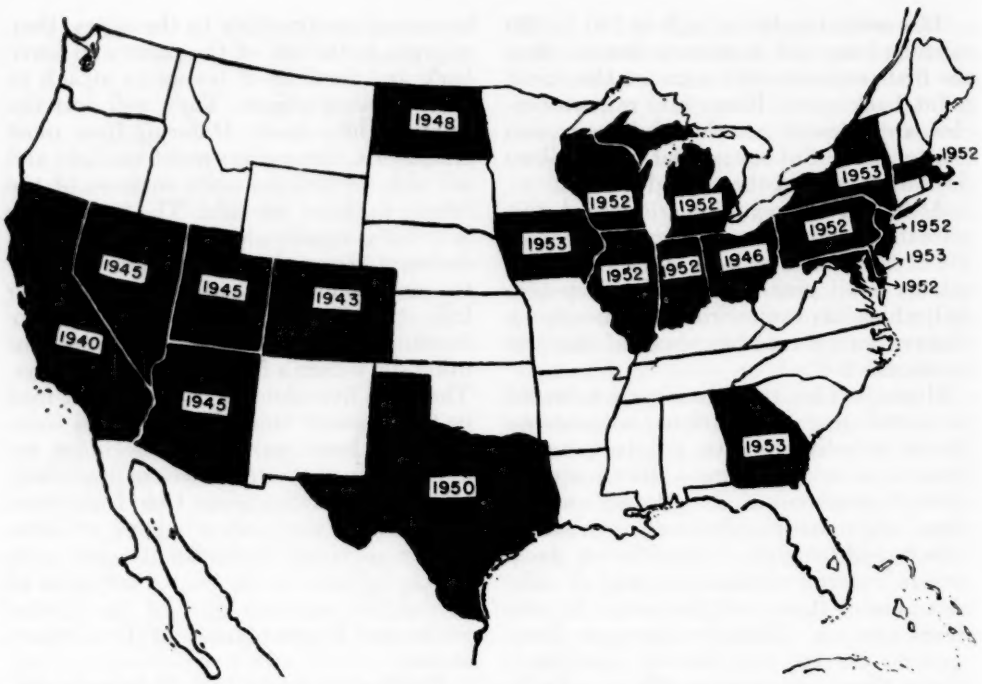


FIG. 2.—Known distribution of tomato russet mite in the United States at the close of the 1953 season. The year of first report for each state is indicated. Reports for North Dakota, New York, Massachusetts, and Wisconsin were single records from greenhouses only; all other states reported field infestations each year after the original record.

of this mite was sent to the entomology departments of all state experiment stations throughout the United States. Replies were received from all the states and the reports are summarized on the map in figure 2. As shown on this map, the tomato russet mite has been found in 20 states. It may occur in others, as several states reported that no search had been made for this pest in their area.

Since the original discovery of this pest in California, in 1940, it has gradually spread across the United States. It was found in Colorado in 1943, in Nevada in 1945, in Arizona in 1945, in Utah in 1945, and in Texas in 1950. Except for Ohio, which reported this mite in a greenhouse in 1946 and in the field each year since, this mite is a relative newcomer to the states east of the Mississippi River. It occurred in Illinois, Indiana, Maryland, Michigan, New Jersey, and Pennsylvania for the first time in 1952, and reoccurred in these states in 1953. Delaware, Georgia, and Iowa were added to the list in 1953. Of the 20 states reporting infestations, Massachusetts (in 1952), New York (in 1953), North Dakota (in 1948), and Wisconsin (in 1952), record only single infestations, all in greenhouses.

Many of the reports from the more northern states indicate that the origin of their infestations was apparently from southern-grown set plants, and that, except for a few greenhouse infestations, this mite probably does not overwinter in their areas. A few of the reports indicated that the mites may be worse during dry seasons.

It appears from these reports that this pest is established and overwinters in many of the southern areas of the United States, and that it is carried north each year on newly set plants, with a few infestations probably originating in the north from overwintering populations in local greenhouses. A more thorough survey should be made to determine the exact distribution in the southern states and to determine how far north this mite can normally survive the winter.

CONTROL.—It was found early that sulfur dust gives good control of this pest. At least 10 pounds of sulfur per acre per ap-

plication is needed, and 1 to 2 treatments may be necessary. Protection may be obtained for 3 to 4 weeks with one application.

Tests by Bailey (1943) in 1941 show that 25 per cent sulfur dust may be used on tomatoes without leaving a deleterious residue on the fruit when canned. Fruit must be thoroughly washed, however, before canning. At present, in California, 75 per cent sulfur is preferred and seldom less than 50 per cent is used. The higher percentage of sulfur is used early in the season when the fruit is small or when it is absent, and the lower percentage is used when treatment is necessary close to harvest time. Thorough plant coverage is essential for good control of this pest.

Thousands of acres of canning and fresh-market tomatoes are treated annually with sulfur for the control of this pest in California. Where the mites can overwinter in the wild, cultural control has not been practicable. However, in more northern areas clean-up of infested plants in greenhouses and other protected places may be of value.

Laboratory acaricide tests have been made at the Citrus Experiment Station during the last few years. The results of the tests have been published by Tuft & Anderson (1953). The methods of rearing and handling these mites for laboratory tests are discussed in that article and will not be reviewed here. In the laboratory tests materials such as toxaphene, parathion, Metacide, *Ovotran*, and endrin were found to be as effective as sulfur in controlling this pest. Malathion, dieldrin, and DDT also gave some degree of control, while materials such as Aramite, TDE, lindane, methoxychlor, chlordane, aldrin, Q-137, and CS-708 were not very effective against this pest.

Preliminary field tests indicate that toxaphene and parathion are effective in the field, and that malathion, though less effective, may help some if dosages and number of treatments are increased.

A. E. Michelbacher of the University of California at Berkeley states in correspondence that this most important pest of tomatoes in California can be readily controlled with timely and thorough applications of sulfur. He also states that the rumor of sulfur-resistant russet mites has not been substantiated in field tests. He also suggests the possibility of using toxaphene for the control of this mite on tomatoes.

Additional information on the tomato russet mite has recently been published by Wilcox & Howland (1954).

SUMMARY.—The tomato russet mite, *Vasates lycopersici* (Massee), has been an important pest in California since 1940, and has appeared in damaging numbers over most of the United States since 1950. It is a small eriophyid mite 150 to 200 microns long which may complete a generation in as little as 7 days. This mite has spread rapidly throughout the United States, but apparently can overwinter only in the warmer, southern part of the United States, where host plants are available throughout the year. Sulfur gives good control of this pest, and it is possible that parathion and toxaphene may prove to be satisfactory substitutes for sulfur.

LITERATURE CITED

Bailey, S. F., and H. H. Keifer. 1943. The tomato russet mite, *Phyllocoptes destructor* Keifer: its present status. JOUR. ECON. ENT. **36**(5): 702–12.

Keifer, H. H. 1940. Eryophyid studies X. Calif. State Dept. Agr. Bul. **29**(3): 160–1.

Keifer, H. H. 1946. Eryophyid studies XIV. Calif. State Dept. Agr. Bul. **35**(1): 39–48.

Keifer, H. H. 1952. The Eriophyid mites of California. Univ. Calif. Bul. California Insect Survey **2**(1): 1–123.

Lamb, K. P. 1953. A revision of the gall-mites (Acarina, Eriophyidae) occurring on tomato (*Lycopersicum esculentum* Mill.), with a key to the Eriophyidae recorded from solanaceous plant. Bul. Ent. Res. **44**(2): 343–50.

Massee, A. M. 1937. An Eriophyid mite injurious to tomato. Bul. Ent. Res. **28**(3): 403.

Rolfs, P. H. 1907. Tomato diseases. Fla. Agr. Expt. Sta. Bul. **91**: 34.

Tryon, H. 1916. Report of the entomologist and vegetable pathologist. Queensland Dept. Agr. and Stock Rept. **1916–17**: 49–63.

Tuft, T. O., and L. D. Anderson. 1953. Acaricides for control of tomato russet mite in California. JOUR. ECON. ENT. **46**(3): 502–4.

Watson, J. R., and A. N. Tissot. 1942. Insects and other pests of Florida vegetables. Fla. Agr. Expt. Sta. Bul. **370**: 109.

Wilcox, J., and A. F. Howland. 1954. The tomato russet mite. U. S. Agr. Res. Serv. Ent. Res. Br E-876.

A Power-Driven Self-Propelled Soil Sifter for Subterranean Insects

W. H. Lange,[1] N. B. Akesson,[2] and E. C. Carlson, [3,4] *University of California, Davis*

In connection with biological and control investigations involving soil insects it is frequently necessary to quickly and relatively accurately determine populations of these insects. The present equipment was designed with the following points in mind: 1) a self-propelled unit that can be moved easily from one plot or part of a field to another with a minimum amount of soil compaction; 2) a machine that can be easily loaded on a pick-up truck; and 3) a unit where the trays with varying screen openings can be quickly interchanged to conform to the relative sizes of the insects and the nature of the soil texture. It is felt that the compactness and the field maneuverability of the present machine are its chief advantages over previously designed equipment. Although designed primarily for wireworm studies it probably could be easily adapted for other soil insects.

Several kinds of machines have been developed to separate soil inhabiting insects from soil. A hand-operated machine was developed by Lane & Shirck (1928) for wireworm population studies. A foot-operated device was used by Donahue (1934) to recover raisin moth larvae from soil. Campbell & Stone (1935) reported a hand-operated soil sifter and a motor-driven machine which were developed in connection with wireworm studies. A similar mobile, power-driven soil sifter was described by Lane & Shirck (1936). A simple hand-operated device for sifting soil and orchard debris was used satisfactorily by Yothers (1938). Gjullin (1938) developed a machine for separating mosquito eggs from soil. Morrill (1939) described a motor-driven sifter for determining populations of wireworms in tobacco fields. A portable soil sifter used for the study of soil insects was reported by Shirck (1941). A fast motion motor-driven machine, which may have application to soil studies, was used by Bacon (1943) to remove insects and eggs from raisins.

A general view of the present machine, and its structural details, are shown in figure 1. The main frame is made up of angle iron ($2'' \times 2'' \times \frac{1}{4}''$) welded construction, and is mounted under the axle to give a 5-inch ground clearance. The maximum over-all dimensions are as follows: width of axle, 46 inches; length from pivot to drive wheel tires, 64 inches; and height from ground to top of steering handles, 49 inches. Soil samples have to be lifted to a height of 41 inches to clear the main frame.

Source of power is a 2.5 horsepower Wisconsin air-cooled gasoline engine. The engine may be operated at from 1,800 to 3,000 r.p.m. and has a built in reduction gear of 3.25 to 1 to the engine drive pulley. This, plus a 4 to 1 drive reduction to the shaker crank shaft (3.25″ engine pulley to 13″ crank-shaft pulley) gives a crank speed variation of 138 to 230 r.p.m. with the above engine speed variation (13 to 1 reduction). With an average engine speed of 2,000 r.p.m. a crank speed of about 154 r.p.m. or 154 forward and backward cycles per minute are produced. This crank speed of about 154 r.p.m. has been found the most satisfactory speed of operation.

An earlier model of a powered shaker provided a certain amount of basic information concerning shaker speeds and throw which was used in designing the present machine. On the present machine four spring steel strap supports (each $1/16'' \times 1'' \times 13''$) carry the weight of the trays and shaking frame. A horizontal motion is imparted to the shaking frame through a 21-inch self aligning ball bearing mounted connecting rod and a crank with a $1\frac{1}{2}$-inch throw; producing 3 inches of total motion in one revolution of the crank. The shaking motion is principally in the horizontal plane, the 13-inch straps on a 3-inch swing raise the tray about 0.1 inch at each end of the motion.

Care must be made in aligning the guides which hold the spring steel straps. It can be shown that in order to insure reasonable life of the spring supports, it is necessary that the guides have a curvature described by an arc with a mini-

[1] Associate Entomologist.
[2] Assistant Agricultural Engineer.
[3] Associate Specialist in Entomology.
[4] The authors acknowledge the assistance of Frank Hall of the Agricultural Engineering shops, who built the present machine.

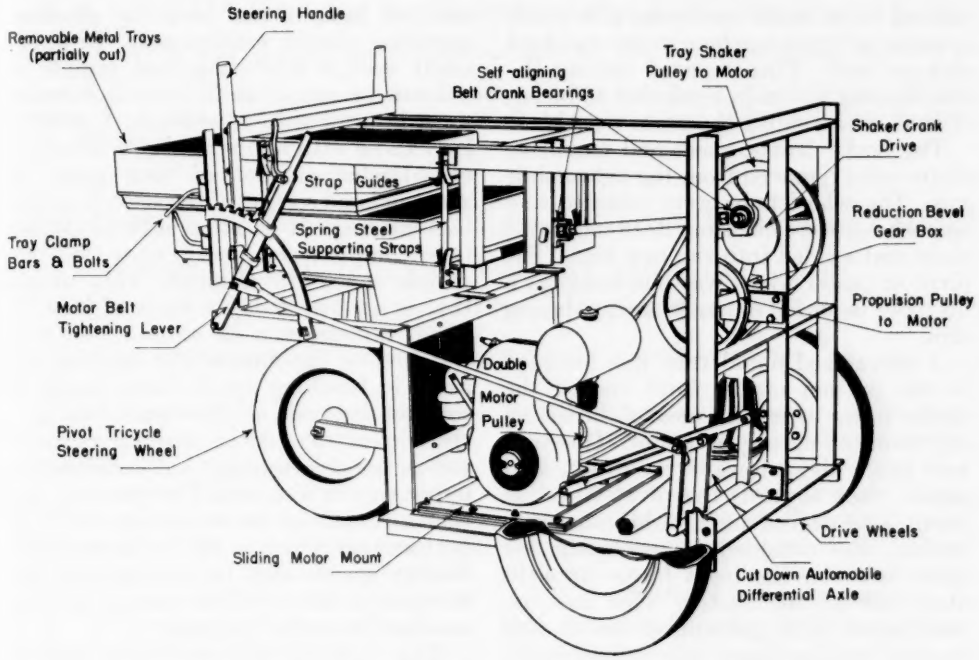


FIG. 1.—Drawing of soil sifter showing structural details.

mum of a 25-inch radius. Without these guides the punched straps will tend to concentrate the bending at one point which may result in early strap failure.

A slipping belt clutch is provided by moving the engine forward to release the drive, and backward to tighten the belt and engage the drive system. The sliding motor mount and connecting linkage is controlled by a notched hand lever on the right of the machine.

To change from shaker to propulsion drive it is necessary to slide the motor forward, remove the shaker belt from the double motor pulley and place the propulsion drive belt in position. The propulsion belt connects the drive on the motor to a bevel gear box which in turn drives the stub propeller shaft of the automobile differential. The automobile ring gear assembly, the gear box, belts and engine gear, provide a total reduction of about 75 to 1 from engine to drive wheels. Thus with 4:00×12 tires (outside tire diameter 20″) the machine will travel from 1.43 to 2.38 mph with an engine speed of 1,800 to 3,000 r.p.m. respectively.

Tray dimensions are 24×30×5 inches. The top is fitted with $\frac{1}{4}$-inch mesh hardware cloth and the bottom with 18-mesh fly screen. Trays are made of 22-gauge galvanized steel with a 1-inch folded face on top and tapered at the bottom, with all joints welded. The screens are supported by angle iron ($\frac{1}{2}''\times\frac{1}{2}''\times\frac{1}{8}''$), all around the bottom, making it possible to remove and change screens when necessary.

Trays fit snugly in the shaking frame and are pulled from this frame for emptying. Two bars fastened to the frame and across the back of the trays are arranged with hand nuts and latches to facilitate quick removal of the trays and yet allow for clamping the trays tightly in position.

A sponge rubber gasket was glued to the bottom of the top tray to insure that no wireworms are lost between the two trays. These rubber gaskets, however, do not support the top tray; they are supported by small angle iron legs at the four corners to protect the gaskets and support the tray weight.

The over-all dimensions of the shaker were adjusted so that it can be conveniently loaded into a standard size pick-up truck. The total weight of the machine, 650 pounds, is not excessive for a truck of this kind. Loading planks strap to the truck bed, and the sifter can be loaded or unloaded on flat ground under its own power.

The automobile axle (64 inches over all)

was cut to 46 inches maximum axle width in order to fit the machine in the standard pick-up body. This required cutting the axle housing and axle, removing 18 inches of each, and welding the parts together.

The brake drums, shoes and mounting plates were removed from the automobile axle. The wheel hubs were retained and new wheels were cut from 3/16-inch steel plate and welded into the new rims. The pivot or caster wheel was purchased as a unit and mounted on an 18-inch swinging arm.

A galvanized metal tray was fastened to the bottom of the front end of the shaker frame to prevent most of the sifting soil from falling on the motor. This tray was made tight toward the front, and angled back towards the pivot wheel at about a 30 degree angle. Additional protection was obtained by enclosing the space between the main frame immediately behind the motor. This was accomplished with galvanized metal, and enough housing space was left immediately behind the motor to allow a full back swing for tightening of the belt.

The machine has been in use for three seasons for a total of about 150 hours and has proved to be dependable in every respect. During this period the only parts that had to be replaced were two of the spring steel strap supports, which were not adjusted properly to the guides. The field maneuverability of the shaker in getting from one plot to another proved to be one of its chief advantages. Adequate power was available to cross all types of plant beds and negotiate soils of all types.

The capacity of the machine is from 0.25 to 0.5 cubic foot of soil at one sifting, depending upon the soil type. A convenient load was 0.33 cubic foot of soil, obtained by sifting a soil unit 6×12×8 inches. Although one man can operate the machine, two men can collect the necessary soil samples and keep the machine operating almost continuously. In light, sandy soils, a 0.33 cubic foot sample of soil can be run in as little as 5 minutes time. In most soils, however, and particularly those with lumps or clay contents, a considerable amount of time must be spent in hand sorting of the soil left on the bottom tray. It is often difficult under these conditions to average more than one sample every 15 minutes. This means that in an 8-hour day a range of from 32 to 96 samples can be sifted. Two men standing on the sides of the machine can assist in breaking up the large lumps of soil and removing any foreign debris from the upper tray. After shaking as much soil as possible through both screens the upper tray is removed. The two men can then sort through the remaining soil of the bottom tray which is left in the machine. Shaker speeds can be changed by the throttle, as there is little need to run the machine at excessive speeds.

This machine may save only from 25 to 50 per cent in time over hand sifting. It has the advantage, however, of doing away with the large amount of back-breaking work and man power necessary with hand equipment. In addition, it allows for the sifting of large numbers of plots over extended periods of time. It was felt that with careful sifting, very few wireworms, except for the smaller sizes, are lost. Good comparative counts of many field soil treatments have been made. It is felt that the extent of wireworm loss is the same for all treatments, and that an accurate count of the sizes of wireworms economically injurious at the time of sampling is obtained, provided adequate samples are taken.

The cost of the machine will vary somewhat, depending upon the availability of second-hand parts, but the present machine was assembled for approximately $500.

LITERATURE CITED

Bacon, O. G. 1943. A fast motion sifting machine. U.S.D.A. Bur. Ent. and Pl. Quar. **ET-209.**

Campbell, R. E., and M. W. Stone. 1935. Soil sifters for subterranean insects. U.S.D.A. Bur Ent. and Pl. Quar. **ET-181.**

Donahue, H. C. 1934. A treadle sifter for examination of soil in studies of insects. U.S.D.A. Bur. Ent. and Pl. Quar. **ET-1.**

Gjullin, C. M. 1938. A machine for separating mosquito eggs from soil. U.S.D.A. Bur. Ent. and Pl. Quar. **ET-135.**

Lane, M. C., and F. H. Shirck. 1928. A soil sifter for subterranean insect investigations. JOUR. ECON. ENT. 21(6): 934–6.

Lane, M. C., and F. H. Shirck. 1936. A mobile power soil sifter. U.S.D.A. Bur. Ent. and Pl. Quar. **ET-70.**
Morrill, A. W. Jr. 1939. A sturdy but compact soil sifter for field use. U.S.D.A. Bur. Ent. and Pl. Quar. **ET-148.**
Shirck, F. H. 1941. A hand-operated shaker for sifting soil. U.S.D.A. Bur. Ent. and Pl. Quar. **ET-185.**
Yothers, M. A. 1938. A simple hand-operated soil-sifting device. U.S.D.A. Bur. Ent. and Pl. Quar. **ET-134.**

Distribution of Third Instar Larvae of the European Chafer and the Efficiency of Various Sampling Units for Estimating Their Populations[1]

R. H. BURRAGE[2] and GEORGE G. GYRISCO, *Cornell University, Ithaca, New York*

In previous work by the authors, now in press, it was found that the distribution of the larvae of the European chafer may vary from instar to instar. There appeared to be a tendency toward a more uniform distribution as the larvae developed. A sampling procedure, satisfactory for estimating populations of larvae during one instar did not appear to be applicable to the same population during other instars. Since sampling populations of the largest stage of European chafer is most easily accomplished, studies on the characteristics of the distribution of the third instar larvae and the efficiency of various size sampling units for estimating populations of them was initiated.

In the spring of 1951, three plots, each 25 feet by 25 feet, were laid out in a permanent hillside pasture on a farm in Ontario County, New York. The pasture covered a section of a drumlin approximately 200 yards long, from the base of the slope on the east side to the base of the slope on the west side. The plots, A, C, and D, were positioned midway between the north and south ends of the field as follows:

Plot A: On the west slope, halfway between the base and the top.
Plot C: On the east slope, halfway between the base and the top.
Plot D: At the base of the east slope.

Within each plot, the soil surface was uniformly flat, and there appeared to be no significant variation in the foliage cover of grasses, clovers, and weeds.

In April and May, 1951, in each of the three plots, every square-foot unit of soil was dug to a depth of 12 inches and examined for European chafer larvae; that is, in each plot, 625 units of soil, each 12 inches square and 12 inches deep, were removed and the number of larvae in each unit was recorded. The unit area of 1 square foot was selected because it was considered to be the smallest which could be conveniently removed from the permanent sod areas. In 1950 the authors used a hollow cylinder, 4 inches in diameter, to remove sampling units of soil from permanent pasture fields; the abundance of stones of various sizes, a condition peculiar to most permanent sod areas that were examined, made it difficult to drive the cylinder into the soil. Further investigations made it apparent that the removal of square-foot units with a shovel required much less labor per unit area of soil examined than the circular units, and the square-foot unit was tentatively adopted as a satisfactory unit of sampling.

Figures 1 and 2 show the layouts of plots A and C respectively, and the distributions of the counts of larvae in the square-foot sampling units. The row and column totals of subdivisions, each consisting of 25 foot-square units, are presented also. In figure 3 the distribution of larval counts in plot D is shown; the infestation of larvae was much lighter than that in either A or C.

Tables 1, 2, and 3, contain the frequency distribution of the observed counts of 0, 1, 2, 3, . . . larvae in the square foot units of soil, and the calculated frequencies for the Poisson and

[1] Thanks are given to W. G. Evans, A. A. Muka, Lemac Hopkins and D. S. Marshall who donated time and labor to the development of some of the work reported here. Special thanks are also given to Dr. R. E. Bechhofer, Visiting Professor in the Biometric Unit of the Department of Plant Breeding at Cornell University for his aid in interpreting the data and other technical assistance.
[2] Now Entomologist at the Dominion Entomological Laboratory at Saskatoon, Saskatchewan.

ROWS	COLUMNS 1					2					3					4					5					TOTAL
	8	8	4	7	7	10	10	7	5	7	8	10	9	6	10	8	7	5	7	7	3	3	7	8	7	
	6	10	3	6	5	5	6	5	4	8	6	5	7	8	4	5	5	7	3	3	5	5	7	7	5	
1	17	7	12	7	8	12	10	10	6	9	4	6	5	4	6	2	5	2	4	8	5	4	3	3	5	808
	12	9	6	2	7	8	4	9	12	3	3	7	9	11	12	8	0	3	7	5	4	2	11	10	9	
	7	12	6	5	2	12	6	18	14	8	3	6	5	7	4	5	5	2	3	6	2	6	3	4	2	
	3	6	5	6	5	4	7	5	9	8	9	8	5	1	6	6	4	4	5	1	3	1	3	10	9	
	7	9	10	7	10	8	8	5	15	4	7	9	8	7	5	1	8	4	1	2	0	3	3	3	5	
2	10	5	6	3	11	9	6	4	7	5	7	5	9	8	7	2	2	0	1	4	1	0	2	3	5	755
	6	6	3	10	7	8	7	7	6	8	3	6	11	8	11	5	4	3	7	5	4	3	5	7	8	
	15	9	13	10	13	17	7	8	9	13	11	4	6	7	5	7	4	3	3	4	5	4	3	5	8	
	10	13	8	6	10	7	6	5	8	6	6	10	10	4	6	7	3	3	5	8	7	5	8	9	9	
	12	10	8	14	18	10	9	8	7	10	8	5	7	4	6	7	5	5	5	7	7	7	6	5	3	
3	10	14	6	8	6	18	12	9	15	14	11	12	8	5	7	6	1	2	7	3	5	6	5	6	10	975
	13	11	5	8	9	8	9	8	13	12	9	6	6	7	7	11	5	7	5	11	6	6	3	10	9	
	6	6	10	5	8	4	5	12	12	16	7	6	14	11	9	5	4	12	4	5	5	4	9	8	6	
	7	10	6	11	9	14	8	10	11	11	10	4	5	15	8	7	5	4	0	4	5	3	6	5	8	
	8	5	8	4	8	3	7	8	12	8	9	12	10	11	12	9	11	10	3	2	2	2	4	5	2	
4	7	12	7	6	5	3	4	3	5	7	7	8	8	7	5	6	4	4	5	2	2	1	3	5	3	659
	3	1	2	0	3	3	8	5	7	10	8	5	11	9	3	3	6	4	3	3	5	1	3	2	3	
	3	2	1	1	1	1	3	1	2	1	0	2	3	2	5	2	6	4	4	1	4	6	1	2	0	
	0	2	3	5	3	1	0	0	2	2	7	4	2	4	8	8	3	5	5	3	3	1	1	3	1	
	5	5	1	1	0	1	2	1	3	0	1	3	2	4	5	3	2	8	5	6	2	0	3	2	3	
5	1	0	0	1	1	3	2	1	1	2	4	3	3	3	3	7	6	5	7	3	3	4	2	3	4	351
	5	1	2	1	0	4	2	3	1	1	4	2	0	0	2	2	3	3	4	3	2	3	2	4	6	
	0	0	2	4	5	3	5	5	5	2	5	4	4	3	4	3	6	2	2	1	2	1	1	3	3	
TOTAL	790					852					792					572					542					AAM

FIG. 1.—The distribution of counts of third instar European chafer larvae in 625 foot-square sampling units of soil, within a permanent pasture plot 25 feet by 25 feet. The number in each foot-square unit in the diagram indicates the number of larvae recovered from that unit. Plot A, Irving DeCann Farm, Ontario County, New York. 1951.

Negative Binomial series having the same means and variance, for plots A, C, and D respectively. The mean number of larvae per square-foot unit of soil, the standard error, the variance, and the standard error of the means for the counts are also given in the tables.

DISCUSSION. — *Distribution.* — The counts of third instar larvae in square-foot units of soil, in plots A, C, and D, decidedly were not distributed at random, since there was a marked tendency for the high counts and the low counts to occur in groups (Figures 1, 2, and 3). While there were obvious differences between subdivisions of 25 square feet, and between the rows and between the columns of the subdivisions, the differences did not appear to be directional. The density of the larval population within each plot then, was not a function of slope or any other orderly gradient, and must be attributed either to heterogeneous environmental conditions in the soil, or an innate tendency of the larvae to congregate.

When a Poisson series, having the same mean, was fitted to the frequencies of the larval counts in each plot, a chi-square test showed that the differences between the observed and calculated values were highly significant. Furthermore, a characteristic of the Poisson series is that the mean of the series is equal to the variance. If, in a set of counts of numbers of individuals per sample area, the relative variance (variance/mean) is greater than unity, the dispersion is greater than would be expected on the assumption of random distribution (Clapham 1936). In each of plots A, C, and D, the relative variance

ROWS	COLUMNS 1					2					3					4					5					TOTAL
	6	4	8	7	8	6	5	12	9	6	8	10	12	8	15	5	14	3	5	4	6	6	6	5	7	
	4	4	4	9	5	11	9	4	7	7	9	8	12	8	10	6	8	7	5	9	5	4	1	7	4	
1	2	1	8	9	6	6	6	9	9	7	9	8	8	10	8	6	12	10	7	9	12	9	8	4	9	825
	1	3	5	6	3	3	4	9	8	9	12	11	12	10	8	7	6	8	6	6	4	5	6	4	3	
	4	2	1	6	7	2	6	4	4	3	7	3	3	6	7	8	6	10	9	4	10	3	3	4	0	
	2	2	6	7	4	4	6	4	6	5	5	10	2	6	6	6	7	3	6	10	7	7	4	4	6	
	4	3	2	4	9	7	5	5	7	9	7	5	5	4	6	6	8	9	7	2	3	3	5	1	4	
2	3	5	2	3	4	6	7	4	6	6	7	6	4	4	4	3	4	3	3	5	6	8	7	4	8	695
	6	3	3	4	5	5	4	7	5	10	3	11	4	6	9	6	4	11	9	9	5	7	7	6	8	
	1	7	2	5	5	4	6	3	3	3	2	10	9	4	5	4	9	8	15	10	9	9	6	9	3	
	2	3	2	4	6	1	4	7	5	5	3	3	3	2	4	8	9	3	4	7	6	9	9	7	8	
	1	2	2	3	5	5	4	4	4	3	6	5	4	5	7	8	7	7	2	4	4	3	9	6	5	
3	4	2	5	3	3	3	7	9	2	2	8	5	3	4	2	5	7	5	4	3	6	5	7	6	5	623
	8	7	5	4	5	3	4	8	8	7	11	9	5	5	8	6	7	3	8	3	3	4	1	6	3	
	2	6	6	5	2	2	2	5	4	7	5	6	4	10	9	10	7	3	5	5	9	5	2	4	3	
	3	2	5	3	2	8	4	2	1	4	6	5	6	7	5	5	7	6	7	8	7	11	5	8	7	
	3	4	5	8	2	6	3	3	5	7	1	5	7	4	4	9	6	4	3	8	4	6	6	5	3	
4	3	4	4	2	5	2	3	7	10	6	5	11	3	3	6	10	6	5	5	5	2	4	7	3	3	641
	3	1	2	0	1	4	8	4	6	6	7	11	3	7	7	6	7	3	11	9	5	2	2	5	5	
	6	2	4	2	0	1	4	8	6	11	3	5	7	4	7	7	8	7	7	11	5	6	5	3	8	
	3	3	3	2	6	3	4	9	5	9	7	6	4	7	5	5	5	6	3	2	3	4	11	8	4	
	8	3	2	1	3	5	2	10	9	12	7	12	8	5	6	6	2	4	3	5	10	5	5	3	3	
5	13	4	1	3	4	7	3	10	7	4	5	6	12	9	9	5	4	4	9	10	6	6	4	3	3	770
	6	6	2	9	8	8	5	7	5	0	2	6	9	9	9	9	9	8	16	14	5	7	9	9	3	
	6	5	6	8	9	10	7	6	3	4	5	4	8	4	5	15	6	12	8	9	4	5	6	13	5	
TOTAL	521					700					810					836					687					AAM

FIG. 2.—The distribution of counts of third instar European chafer larvae in 625 foot-square sampling units of soil, within a permanent pasture plot 25 feet by 25 feet. The number in each foot-square unit indicates the number of larvae recovered from that unit. Plot C, Irving DeCann Farm, Ontario County, New York. 1951.

was greater than unity; one may assume, from this relationship, that the larvae were not distributed at random throughout any one of the plots, and the inference is supported by the patterns of dispersal shown in figures 1, 2, and 3.

The frequencies of the counts in each of plots A and C, however, approximated the Negative Binomial series calculated in each (Tables 1 and 2) so that, when the chi-square test for goodness of fit was applied, the discrepancies were not highly significant. In plot D the chi-square value determined for the same test, was highly significant. There were only three degrees of freedom with which to test the hypothesis, however, and the calculated chi-square value is only slightly greater than that significant at the .01 level; also, the fit of the Negative Binomial series was better than that for the Poisson series. The evidence available indicates, then, that the non-random distribution of the counts of larvae in each of the plots is better characterized by a Negative Binomial series.

The usefulness of a procedure for sampling insect populations is a function of the accuracy of the estimate derived from a sample and the amount of work required to obtain it. Generally, for a sample of given size (area), a large number of small units well-distributed will give a better estimate of the population than a few large units. Fleming & Baker (1936) concluded that, from a consideration of the standard deviations, the standard errors of the means, and the concentrations of the units about the median, foot-square sampling units were more dependable, than larger units, for estimating populations of Japanese beetle larvae. While

ROWS	COLUMNS 1					2					3					4					5					TOTAL
	1	1	1	1	2	1	1	2	1	3	4	1	2	2	1	1	2	1	1	3	1	1	1	2	4	
	3	1	2	0	1	0	4	2	3	0	1	0	3	6	1	1	0	0	0	2	0	2	3	1	1	
1	0	0	0	3	1	2	0	1	1	1	0	0	1	0	1	0	3	1	0	0	1	0	3	3	3	153
	0	0	2	1	0	1	0	0	1	0	0	0	1	1	3	0	0	0	1	4	3	1	0	3	0	
	0	0	1	0	1	1	2	2	0	0	0	0	0	3	1	1	3	1	3	3	3	1	0	1	1	
	0	0	0	1	0	2	0	0	1	1	1	0	0	2	3	3	3	2	2	3	1	2	2	2	0	
	0	0	0	0	1	0	0	2	0	2	1	1	2	3	0	2	1	1	2	1	1	2	3	0	1	
2	0	0	0	0	0	0	0	1	0	0	1	1	1	3	0	1	2	3	2	2	1	0	1	0	0	124
	0	0	2	0	1	0	1	0	1	0	2	0	0	2	2	4	0	1	2	3	0	0	2	0	0	
	0	0	0	0	1	0	0	0	1	0	0	0	1	2	2	2	1	2	5	3	1	0	2	2	0	
	0	0	0	0	0	1	2	0	0	2	0	2	1	2	1	0	0	2	1	2	5	0	1	0	1	
	0	1	0	2	0	0	0	1	2	0	1	1	1	1	0	2	0	4	1	1	4	4	3	2	0	
ROWS 3	0	1	0	1	0	0	0	0	0	0	1	0	0	2	1	2	0	2	1	1	4	1	2	0	0	97
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	1	2	0	1	1	
	0	1	1	0	1	1	0	0	0	1	0	0	3	0	1	0	0	1	0	3	0	0	1	0	0	
	2	0	2	0	0	0	1	0	0	0	0	4	2	2	2	2	1	3	1	0	0	0	0	0	0	
	0	0	0	0	1	0	0	0	0	0	1	2	0	0	1	2	2	2	2	2	2	1	1	0	0	
4	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	2	0	0	0	1	1	1	0	0	66
	0	0	0	0	0	2	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	
	0	0	0	0	0	0	0	0	0	1	0	0	3	2	1	1	0	0	0	0	1	1	0	0	0	
	1	0	0	0	0	0	0	3	0	0	0	0	0	3	1	0	0	0	0	3	1	1	0	0	1	
	0	0	1	0	0	1	0	0	0	1	0	0	0	0	2	1	0	1	1	0	0	0	0	1	1	
5	1	1	1	2	0	0	2	0	0	1	0	0	2	0	2	5	0	0	2	1	2	1	2	2	0	95
	0	0	1	1	1	0	0	0	0	1	1	1	5	3	3	1	1	1	2	1	1	2	2	1	0	
	1	0	0	1	0	0	0	0	0	0	0	3	1	1	2	1	1	1	1	0	0	1	1	0	0	
TOTAL			54				69					133					154					125				AAM

FIG. 3.—The distribution of counts of third instar European chafer larvae in 625 foot-square sampling units of soil, within a permanent pasture plot 25 feet by 25 feet. The number in each foot-square unit in the diagram indicates the number of larvae recovered from that unit. Plot D, Irving DeCann Farm, Ontario County, New York. 1951.

Jones (1937) concluded that counts of wireworms in foot-square units of soil gave better precision than counts in smaller units, Yates & Finney (1942) and Finney (1946) found that small sampling units were more efficient than larger ones, except for populations of low density.

Finney (1946) devised a method for comparing the efficiencies of different sized sampling units in terms of the total sample area needed to give equal precision in the population estimates; if units with surface areas u_1 and u_2 have sampling variances of v_1 and v_2 respectively (measured on the same scale of population density), samples of the total areas A_1 and A_2 will lead to estimates of equal precision if $u_1v_1/A_1 = u_2v_2/A_2$, and the efficiency of the second unit relative to the first is then A_1/A_2. Three hundred each of three sizes of sampling units were selected at random from each plot A, C, and D (Figures 1, 2, and 3):

(1) 1 square foot (1 foot by 1 foot)
(2) 4 square feet (2 feet by 2 feet)
(3) 9 square feet (3 feet by 3 feet)

The variance of each unit size, and the variance per square foot for each unit size, for the counts in each of plots A, C, and D, are given in table 4.

In plot A, for example, the efficiency of a 1-square-foot unit may be compared to that of a 4-square-foot unit as follows:

Samples of total areas A_1 and A_2 will lead to estimates of equal precision if $u_1v_1/A_1 = u_2v_2/A_2$, that is $(1\times11.97)/A_1 = (4\times7.55)/A_2$, and the efficiency of the 1-square-foot sampling unit relative to the 4-square-foot unit is A_2/A_1 which is $(4\times7.55)/(1\times11.97) = 2.52$.

Since the variance per square foot for

Table 1.—The distribution of counts of third instar European chafer larvae in 625 units of soil, each 12 inches square and 12 inches deep, from a plot 25 feet by 25 feet. Plot A, Ontario County, New York. April, 1951.

No. of 3rd Instar Larvae (n)	No. of Units Containing n Larvae (x)	Calculated Value of x for Poisson Series	Calculated Value of x for Negative Binomial Series
0	21	2	13
1	40	12	37
2	51	34	59
3	81	65	74
4	56	92	79
5	86	105	76
6	56	100	67
7	63	81	56
8	54	58	44
9	29	36	34
10	31	21	25
11	17	11	19
12	18		13
13	6		8
14	6		5
15	4		
16	1		
17	2 Remainder	8 Remainder	16
Total	625	625	625
Chi-square for goodness-of-fit test		415.55[1]	29.30
Mean no. of larvae per square-foot unit		5.6768	
Standard deviation of 625 observations		3.45	
Variance of 625 observations		11.8891	
Standard error of the mean		0.14	

[1] Highly significant.

the 1-square-foot unit is 11.97, and the variance per square foot for the 4-square-foot unit is 7.55, the number of square-foot units required to obtain the same variance per square foot, as that of a 4-square-foot unit, is $11.97/7.55 = 1.59$. Theoretically, this means that 1.59 square-foot units must be sampled to give the same precision of estimate (per square foot) as that obtained from a single 4-square-foot unit. The ratio of the areas (the larger to the smaller) sampled is

Table 2.—The distribution of counts of third instar European chafer larvae in 625 units of soil, each 12 inches square and 12 inches deep, from a plot 25 feet by 25 feet. Plot C, Ontario County, New York. April, 1951.

No. of 3rd Instar Larvae (n)	No. of Units Containing n Larvae (x)	Calculated Value of x for Poisson Series	Calculated Value of x for Negative Binomial Series
0	4	2	4
1	16	12	19
2	45	34	44
3	81	65	70
4	89	92	89
5	86	105	93
6	84	100	84
7	67	81	69
8	48	58	54
9	53	36	37
10	21	21	24
11	12	11	15
12	11		9
13	2		
14	2		
15	3 Remainder	8 Remainder	14
16	1		
Total	625	625	625
Chi-square for goodness-of-fit test		39.38[1]	11.38
Mean no. larvae per sq.-ft. unit		5.6864	
Standard deviation of 625 observations		2.74	
Variance of 625 observations		7.5241	
Standard error of the mean		0.11	

[1] Highly significant.

Table 3.—The distribution of counts of third instar European chafer larvae in 625 units of soil, each 12 inches square and 12 inches deep, from a plot 25 feet by 25 feet. Plot D, Ontario County, New York. April, 1951.

No. of 3rd Instar Larvae (n)	No. of Units Containing n Larvae (x)	Calculated Value of x for Poisson Series	Calculated Value of x for Negative Binomial Series
0	311	267	283
1	171	227	210
2	89	97	92
3	39	27	30
4	10	6	8
5	4		
6	1 Remainder	1 Remainder	2
Total	625	625	625
Chi-square for goodness-of-fit test		35.73[1]	15.13[1]
Mean no. larvae per sq.-ft. unit		0.8512	
Standard deviation of 625 observations		0.9770	
Variance of 625 observations		0.9546	
Standard error of the mean		0.04	

[1] Highly significant.

Table 4.—The variance of counts of third instar European chafer larvae in 300 each of square-foot units, 4-square-foot units, and 9-square-foot units, and the variance per square-foot for each unit size.[1] Ontario County, New York, 1951.

Plot	Size of Sampling Unit	Variance	Variance per Square Foot
A	1 square foot (1 ft. by 1 ft.)	11.97	11.97
	4 square feet (2 ft. by 2 ft.)	120.89	7.55
	9 square feet (3 ft. by 3 ft.)	439.46	5.42
C	1 square foot (1 ft. by 1 ft.)	6.62	6.62
	4 square feet (2 ft. by 2 ft.)	54.05	3.38
	9 square feet (3 ft. by 3 ft.)	181.54	2.24
D	1 square foot (1 ft. by 1 ft.)	1.23	1.23
	4 square feet (2 ft. by 2 ft.)	9.02	.56
	9 square feet (3 ft. by 3 ft.)	29.93	.37

[1] Three hundred units, of each size, were drawn from each of 3 permanent pasture plots A, C, and D (Figures 1, 2, and 3).

Table 5.—The efficiencies of different sized sampling units compared in terms of the total sample areas needed to give equal precision in the population estimates.[1] Ontario County, New York. May, 1951.

Plot	Mean No. Larvae (per Sq. Ft.)	The Efficiency of the First Unit Relative to the Second		
		1-Sq.-Ft.: 4-Sq.-Ft.	1-Sq.-Ft.: 9-Sq.-Ft.	4-Sq.-Ft.: 9-Sq.-Ft.
A	5.68	2.52	4.07	1.62
C	5.69	2.04	3.04	1.49
D	.85	1.82	2.73	1.50

[1] The variance for each unit was determined from 300 examples drawn at random from each of Plots A, C, and D (Figures 1, 2, and 3).

4/1.59 = 2.52, which is the efficiency of the 1-square-foot as compared to the 4-square-foot unit, obtained from Finney's formula. The calculated relative efficiencies for the different unit sizes of plots A, C, and D, are given in table 5.

Sample Size.—It is apparent, from the data in table 5, that in each of the plots sampled the 1-square-foot sampling unit was more efficient than the 4-square-foot unit or the 9-square-foot unit. The means of plots A and C were very similar, although the variance in plot A was considerably higher than that in plot C, and the efficiencies of one unit relative to another were approximately the same in both plots. In plot D, even though the mean number of larvae per square foot was less than one, the smaller sampling units were obviously more useful than the larger ones. The data indicate that, in the plot samples, the 1-square-foot unit was approximately twice as efficient as the 4-square-foot unit and three to four times as efficient as the 9-square-foot unit; the 4-square-foot unit was between one and two times as efficient as the 9-square-foot unit.

From a practical point of view the efficiencies of the smaller sampling units, relative to the larger ones, were less than the calculated values in table 5; it takes longer to obtain counts of larvae, in a sample of a given area, when the sample is divided into a number of small units scattered over a field than when it consists of a small number of larger units.

SUMMARY.—Counts of third instar larvae, from foot-square sampling units, were not distributed at random within plots 25 feet by 25 feet, in permanent pasture sod; instead, there was a tendency for the larvae to be scattered in clumps so that there were more high and low counts of larvae than would be expected in random distributions. In each plot examined, the counts were more closely approximated by a negative binomial series than by a Poisson series.

The relative efficiencies of 1-square-foot, 4-square-foot, and 9-square-foot sampling units were determined by comparing the area sampled with each unit to give a population estimate of the same precision. By these determinations, each of the units was more efficient than any one larger than it, so that the 1-square-foot unit was the most efficient of those tested.

LITERATURE CITED

Clapham, A. R. 1936. Over-dispersion in grassland communities and the use of statistical methods in plant ecology. Jour. Ecology **24**: 232–51.

Finney, D. J. 1946. Field sampling for the estimation of wireworm populations. Biometrics Bul. 2(1): 1–7.

Fleming, W. E., and F. E. Baker, 1936. A method for estimating populations of larvae of the Japanese beetle in the field. Jour. Agr. Res. **53**(5): 319–31.

Jones, E. W. 1937. Practical field methods of sampling soil for wireworms. Jour. Agr. Res. **54**(2): 123–34.

Yates, F., and D. J. Finney. 1942. Statistical problems in field sampling for wireworms. Ann. Appl. Biol. **29**(2): 144–96.

The Effects of the Second Generation European Corn Borer on Field Corn[1]

H. C. Chiang,[2] L. K. Cutkomp, and A. C. Hodson[3]

The larvae of the European corn borer affect the yield of field corn by reducing the growth of the ears and also by causing stalk breakage and ear dropping. The latter two effects may increase harvest waste, particularly with mechanical picking. Some years ago a damage index of a three per cent loss per borer per stalk was established for estimating the loss in field corn due to single generation borer infestations, Patch *et al.* (1942). This damage index may be valid in areas where a single generation of the borer is predominant. However, the same index is now used in the north central states region where often there are two generations of corn borers. The infestation estimate is made in the fall to determine the loss in yield resulting from damage by borers during a growing season. Thus, both first and second generation borers are often involved.

The use of this index in a two-generation area has involved some practical problems. For example, workers have raised such questions as when should the number of borers be checked and what larval instars should be included in the checking. Considerable effort has been made to standardize the readings to improve the reporting of corn borer abundance. However, little experimental work has been directed at determining the basic soundness of the application of the three per cent damage index to infestations involving two generations of the corn borer.

In 1951 a special session was held to discuss the basic and practical problems involved in censusing borer populations and in estimating their damage to field corn (North Central States Branch of the American Association of Economic Entomologists). One of the basic problems emphasized was the effect of the second generation borer on field corn. The present paper presents the results of some studies related to this problem and discusses their significance to the method of damage estimation which is in current use in the North Central States.

Methods and Procedure.—The study was made at the Southeast Experiment Station, University of Minnesota, Waseca, Minnesota, during 1952. Some data secured in the years 1948 to 1951 are used in discussing certain points.

A variety of field corn adapted to the region and in common use, Minhybrid 408, was planted on two dates, May 15th and May 29th in 1952. Both dates were within the period of field corn planting in south central Minnesota that year.

Records were taken of numbers of borers, stalk breakage, and ear dropping due to borer damage, and the yield of corn in the plots.

Results.—The results will be presented and discussed in two sections: (1) the effect of second-generation borers on the yield of corn and (2) their effect on stalk breakage and ear dropping.

Effect of second generation borers on yield of corn.—The natural infestation by the first generation borers was very low in the experimental fields during 1952. The results in table 1 show a very low number of egg masses from the first generation but considerably higher egg mass counts from second generation borers. The second planting (May 29) had a count of 95 egg masses per 100 plants. When there are 100 egg masses per 100 plants insecticide treatment is recommended.

The second planting was used to deter-

Table 1.—Egg populations of the first and second generations of the European corn borer in two plantings of field corn.

Number of Egg Masses per 100 Plants	Planting	
	First	Second
First generation		
Total	11.3	4.0
Maximum[1]	2.7	1.3
Second generation		
Total	175	295
Maximum[1]	90	95

[1] Greatest number found on any 1 day.

[1] Paper No. 3150 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

[2] Present address: Biology Dept., Duluth Branch, Duluth, Minnesota.

[3] Grateful acknowledgment is due to Mr. R. E. Hodgson, Superintendent of the Southern School and Experiment Station of the University of Minnesota, who provided the field plots and material assistance.

Table 2.—Number of European corn borers per 100 plants in sprayed[1] and unsprayed plots in the second planting of field corn, 1952.

	SEPTEMBER 16	OCTOBER 6
Unsprayed plots	315	364
Sprayed plots	75	60
Per cent reduction	76.2	83.4

[1] Applications were made September 3 and 10.

mine the effect on the yield when corn was sprayed to reduce the second generation borer population. Four plots, each 10×30 hills, were hand sprayed with an emulsion of DDT (1½ pounds of actual DDT per acre) at the end of the second generation oviposition period and again 1 week later (September 3rd and 10th). Four untreated plots of the same size were alternated with the treated plots. There was no spraying done in the first planting. Counts of the borers were made 1 week and 3 weeks following spraying. The results showed a difference of 83.4 per cent in the number of borers in the sprayed and the unsprayed plots 3 weeks after spraying (Table 2).

Stalk breakage and ear dropping was also determined in both the sprayed and unsprayed plots and in the first planting which was untreated. Ear dropping was negligible in all plots, but stalk breakage was less extensive in the first planting than in the second planting. The unsprayed plots had more than twice as many broken stalks as the sprayed. Consult table 3 for details.

The yield of corn was determined in the following manner. Ears from 30 plants in each of the replicates were weighed in the field. The moisture content was determined from subsamples of 12 ears each. From the green weight and the moisture content, dry weight of the ears was determined. These values were converted into yield expressed in number of bushels per acre of shelled corn at 14.5 per cent moisture. The results show that the yield in the first planting averaged appreciably higher (90.4 bu. per acre) than in the second planting, but that the average yield in the sprayed (81.4 bu. per acre) and the unsprayed plots (83.8 bu. per acre) of the second planting was not significantly different.

The number of borers was determined October 14 by dissecting 44 plants at random from each planting. In the usual fall corn borer survey the numbers of larvae are recorded regardless of their generation. In the present study a distinction was made between the number of first and second generation borers present by the method described by Chiang & Hodson (1952). The results (Table 4) show that the total number of borers, irrespective of the generation from which the borers originated, was considerably higher in the second planting than in the first planting. Using the current method of estimating the loss in yield by multiplying the number of borers per plant by a damage index of 3 per cent, the loss suffered by the second planting was estimated to be noticeably higher than that suffered by the first planting. The significance of the role of the two generations in affecting yield will be developed presently.

The data indicate that even though the

Table 3.—The percentages of stalk breakags and ear dropping in plots of field corn, on datee indicated.

1952	FIRST PLANTING	SECOND PLANTING	
		Unsprayed	Sprayed
September 30			
Total plants examined	—	697	717
Per cent of			
tassels broken	—	6.7	6.0
stalks broken above the ear	—	10.5	2.8
stalks broken below the ear	—	0.4	0.3
ears dropped	—	0.1	0
October 13			
Total plants examined	337	353	360
Per cent of			
stalks broken above the ear	8.0	20.0	9.1
stalks broken below the ear	1.5	2.0	0
ears dropped	0	0	0
October 24			
Total plants examined	277	281	269
Per cent of			
stalks broken below the ear	2.9	0.7	0.7
ears dropped	0	0	0

Table 4.—Populations of the European corn borer October 14, 1952, and the estimated loss in yield[1] in two plantings of field corn.

	PLANTING	
	First	Second
Average number of mature borers per 100 plants		
First generation	6.8 (16.7%)[2]	2.3 (3.3%)
Second generation	34.1 (83.3%)	65.8 (96.7%)
Total	40.9	68.2
Per cent loss in yield estimated on the basis of the total number of mature borers	1.2	2.0
Per cent loss in yield estimated on the basis of the number of the first generation mature borers alone	0.2	0.1

[1] The loss in yield was estimated at three per cent per borer per plant.

[2] The relative proportion of the two generations is given in parenthesis.

second generation borer population in the sprayed plots was 83 per cent less than in the checks (60 as compared to 364 borers per 100 plants), the yield in these plots was not increased over that in the unsprayed plots where a higher borer population was present. The results would indicate that the presence of the additional 83 per cent (244 more borers per 100 plants) of the second generation borer population did not significantly affect the yield. Since the sizeable numbers of second generation borers could not be shown to significantly affect the yield and since the numbers of first generation borers was especially low (less than 3 borers per 100 plants) one could conclude that the effect of the borers on the yield was not detectable, or nil. At least we may say that the loss in yield in the second planting would be smaller than that in the first planting, because the latter had a little higher infestation by the first-generation borers. Yet, according to the estimates made on the basis of the current method (which includes both generations), the loss in yield in the second planting (2.0%) was greater than that in the first planting (1.2%), as shown in table 4.

This contradiction is due to the fact that the effect of the second generation borers on the yield of corn is overestimated with the current method of estimating the loss in yield. In the present case, where there was no evidence of a significant loss in yield due to second generation borers, an estimate made on the basis of the number of the first generation borers alone may be more accurate. As shown in table 4, the losses in yield estimated in this manner are much smaller than those estimated with the current method in both plantings. Furthermore, the loss estimated in this manner is smaller in the second planting than in the first planting.

The above discussion suggests that under the conditions of this study the loss in yield estimated with the current method is erroneous, whereas an estimate made on the basis of the first generation population alone may be more accurate. However, Deay *et al.* (1949) showed that the effect of second generation borers on the yield of corn may be influenced by the variety of corn, by the normal yield of the corn in the absence of borers, and by the stage of corn growth at which the borer infestation is initiated. In the present case, the insignificant effect of the second generation borers is probably attributable to a late occurrence of the second generation borer infestation with respect to the plant growth. A late occurrence of second generation borers is to be expected in the north central states.

The significant point of the present discussion is that the effect of the second generation borers on yield (whether negligible or significant) must be evaluated with due consideration of the factors which may modify this effect. The results indicate the need for an evaluation separate from the effect of the first generation borers.

Effect of second generation borers on stalk breakage and ear dropping.—Another aspect of the effect of the second generation borers on the field corn is the stalk breakage and ear dropping. Records were

Table 5.—Egg population, population of mature larvae, stalk breakage and ear dropping in seven plantings of field corn, 1948 to 1952.

Year	1948	1949		1950	1951	1952	
Variety (Minhybrid No.)	505	503		504	608	408	
Planting date	5/15	5/3	5/17	5/22	5/22	5/15	5/29
Egg masses per 100 plants							
First generation	27	274	59	212	121	10	4
Second generation	46	217	490	90	19	175	295
Mature larvae per 100 plants during late fall							
First generation	47	11	22	217	160	7	2
Second generation	64	136	194	0	0	34	66
Per cent stalks broken above the ear	13.6	40.1	29.1	2.4	1.7	8.0	20.0
Per cent stalks broken below the ear	10.1	21.6	43.4	3.7	2.1	1.5	2.0
Total per cent of stalks broken	23.7	61.6	72.5	6.1	3.8	9.5	22.0
Per cent ears dropped	2.5	6.3	26.3	0	0.1	0	0

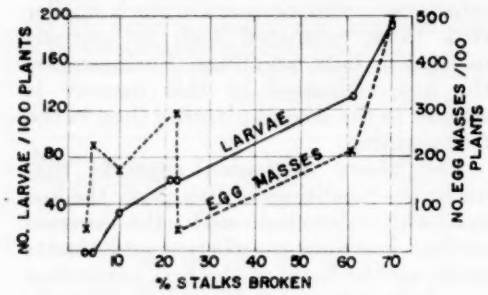


FIG. 1.—The relationships between the per cent of stalks broken and the number of second generation egg masses per 100 plants (scale on the right) and the number of second generation mature larvae per 100 plants (scale on the left) in seven plots of field corn, 1948 to 1952, Waseca, Minnesota.

kept on the per cent of stalks broken and of ears dropped in the experimental plots at the Southeast Experiment Station, Waseca, Minnesota, 1948 through 1952. The effect of stalk breakage and ear dropping on the efficiency of mechanical picking was discussed in an earlier paper (Chiang & Hodson 1950). The relationships between the borer population and the amount of stalk breakage and ear dropping will be discussed in the following paragraphs.

Table 3 shows that the amount of stalk breakage was smaller in the sprayed plots than in the unsprayed plots (9 per cent in contrast to 20 per cent) and was smaller in the first planting than in the second planting. It appears that the amount of stalk breakage in the different plots varies in the same direction as does the number of second generation larvae. To examine this relationship more thoroughly, the egg population, the population of mature larvae during the fall, the amount of stalk breakage and ear dropping recorded in seven experimental plantings during the years 1948 to 1952 are tabulated (Table 5), and illustrated (Figures 1 and 2) and show three significant points discussed below.

In the present study the amount of stalk breakage and ear dropping was not apparently affected by the size of the first generation borer population. This fact should not be interpreted as indicating that no relationships could have existed between the first generation borer population and stalk breakage. In fact, extensive stalk breakage has been reported in Ontario, Canada, where there was only one generation of borer infestation (Ficht, unpublished data[4]). The present results probably are due to two conditions. First, in the years when borer infestations of both generations occur any effect on the corn stand that the first generation borers may have had would be attributed to the second generation borers if they were most abundant at the time of the fall survey. Secondly, in those years when the second generation borer population is very low so that the effect of the first generation borers on stalk breakage could become manifest, the stalk breakage by the first generation might be reduced by the same weather conditions that suppressed the second generation population. As a result stalk breakage by the first generation borers usually is not assessed fairly at the time of the fall survey.

The coefficients of correlation between the numbers of second generation egg masses and of second generation larvae, and the per cent of stalk breakage and ear dropping as given in table 5 are calculated as follows:

Egg mass and stalk breakage	0.75
Egg mass and ear dropping	0.74
Larvae and stalk breakage	0.94
Larvae and ear dropping	0.85

It is shown that the amount of stalk breakage is not as well correlated with the number of second generation *egg masses* as with the number of second generation *larvae* (Fig. 1). This fact has an important practical implication. The insecticidal treatment for the second generation borers in field corn often is aimed at reducing the amount of stalk breakage and ear dropping. Since the decision on the need for such a treatment is made on the basis of the number of second generation egg masses, it is apparent that such decisions may not be correct in some cases. The fact that the amount of stalk breakage is not as well correlated with the number of second generation egg masses as with the number of second generation mature larvae is primarily due to the highly variable

[4] An unpublished "Report of European corn borer investigations," Wheatley, Ontario, 1925 by the late G. A. Ficht at the Canadian Department of Agriculture. Sincere thanks are due to Dr. H. L. Seamans, Head, Field Crop Insect Unit, Canadian Department of Agriculture, who kindly made the report available to the authors.

mortality which the eggs and larvae may suffer during different seasons. The variation in the mortality of the second generation during the past 5 years has been considerably greater than the variation among first generation borers (Chiang & Hodson 1952). Actually, mortality of the second generation was 100 per cent in the experimental fields in the years 1950 and 1951. The amount of stalk breakage during these years was extremely low regardless of the number of the second generation egg masses which were present earlier in the season.

The third point concerns the higher correlation between the amount of stalk breakage and the number of second generation mature borers. While this relationship holds true for the present study, one must realize that this relationship may not always be as pronounced due to other factors. Two such factors can be cited: Chiang & Hodson (1950) showed that with the same degree of borer infestation the amount of stalk breakage and ear dropping increased with a prolonged weathering of the stalks, and Patch, *et al.* (1951) showed that it also varies with the variety of corn.

SUMMARY AND CONCLUSIONS.—Results of some observations are presented on the effects of the second generation corn borer on the yield and the stalk breakage and ear dropping of field corn, and the method of estimating the loss in corn yield due to borer infestations in two-generation areas in the light of these results is discussed.

Records were taken on the number of egg masses, the number of larvae, the amount of stalk breakage and ear dropping and the yield in two plantings of field corn in Waseca, Minnesota, in 1952. The first generation borer population was very low in both plantings. The second generation borer population was much higher; in the second planting the egg mass counts were very close to the critical level at which an insecticidal treatment is recommended. The second generation larval population in some plots in the second planting was reduced by 83 per cent by two DDT sprays applied 1 week apart. The yield in the sprayed and unsprayed plots was estimated to be not significantly different. Thus, the use of the current method of estimating the loss in yield which attributes a three per cent loss to each borer found, whether first or second generation, would overestimate the loss.

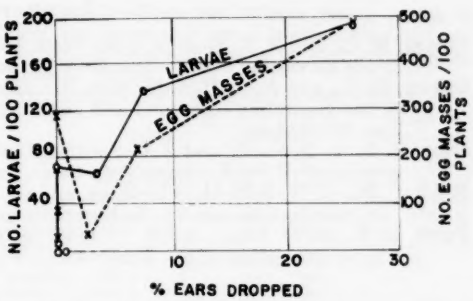


FIG. 2.—The relationships between the per cent of ears dropped and the number of second generation egg masses per 100 plants (scale on the right) and the number of second generation mature larvae per 100 plants (scale on the left) in seven plots of field corn, 1948 to 1952, Waseca, Minnesota.

The amount of stalk breakage and ear dropping was compared with the number of overwintering larvae of both generations. The amount of stalk breakage and ear dropping was more poorly correlated with the number of second generation egg masses than with the number of second generation overwintering larvae. Thus, if the insecticidal treatment for the second generation borer infestation were primarily aimed at reducing stalk breakage and ear dropping, the decision of the need for such treatments made on the basis of the number of egg masses present in the summer would not be correct under some circumstances.

These data indicate that the second generation borers have little effect on the ear growth, but are responsible for stalk breakage and ear dropping. Since the effect of stalk breakage and ear dropping on yield is indirect and indefinite (depending upon whether hand gleaning after mechanical picking is possible), there is little basis for assigning the same damage index to both the first and the second generation borers. It is concluded that the populations of first and second generation borers must be distinguished, and that their effect on the loss in yield must be assessed separately although the distinction may be difficult to make in a large scale field survey. However, attempts to handle the losses due to borers of the two generations as one problem may commonly result in erroneous estimates.

LITERATURE CITED

Chiang, H. C., and A. C. Hodson, 1950. Stalk breakage caused by European corn borer and its effect on the harvesting of field corn. JOUR. ECON. ENT. **43**: 415–22.

Chiang, H. C., and A. C. Hodson, 1952. Relation between egg mass abundance and fall populations of first generation corn borer and justification for insecticidal control in field corn. JOUR. ECON. ENT. **45**: 320–3.

Deay, H. O., L. H. Patch, and R. O. Snelling, 1949. Loss in yield of dent corn infested with the August generation of the European corn borer. JOUR. ECON. ENT. **42**: 81–7.

Patch, L. H., G. W. Still, M. Schlosberg, and G. T. Bottger. 1942. Factors determining the reduction in yield to field corn by the European corn borer. Jour. Agr. Res. **65**: 473–82.

Patch, L. H., H. O. Deay, and R. O. Snelling. 1951. Stalk-breakage of dent corn infested with the August generation of the European corn borer. JOUR. ECON. ENT. **44**: 534–9.

Summer Control of Pear Leaf Blister Mite

H. P. LANCHESTER, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The pear leaf blister mite, *Eriophyes pyri* (Pgst.), has been held under control normally by the dormant sprays, but sometimes they are omitted, especially on young trees, or are poorly applied. Consequently there has been some loss of growth on young trees, and occasionally the fruit of mature trees has become russeted or even deformed, for little could be done to control this pest during the growing season. Since the mites are sheltered within leaf blister, sprays do not reach them. With the advent of systemic sprays it seemed possible that the mites could be reached within the blisters.

In August 1952 severely damaged young pear trees in the Yakima Valley of Washington were sprayed with 42 per cent demeton (Systox) emulsifiable concentrate at ½, 1, and 2 pints per 100 gallons and with 15 per cent parathion wettable powder at 1 pound per 100 gallons. Only the lower half of each tree was sprayed, to determine whether there was movement of the chemical upward into unsprayed portions of the tree.

Much time was spent in studying mite activity within the blisters. Many of the blisters had grown together, and much of the damaged tissue had died. Fresh feeding and most of the mite activity were near the margins of the blisters, and it was extremely difficult to make counts. Better counts could be made in the smaller blisters, but even in them counts often reached into the hundreds. Disturbed mites frequently feigned death for a time, whereas others harbored lethal dosages of insecticides without any evident sign.

After a month many of the recently developed blisters from the treated areas appeared to contain no mites at all, and were recorded as dead. In others mites were found but not one was observed to move; they were indicated as inactive. Other blisters were full of mites, some of which were seen to move. If any mite was seen to wiggle, the blister was reported as active. This method heavily weighted the count against the "dead" blisters.

In September 100 blisters in leaves collected at random from both the sprayed and unsprayed portions of at least five trees receiving each treatment were examined (Table 1). It was found that the parathion had had some effect within the area sprayed. There was no evidence that parathion had had any effect in the unsprayed portion of the tree, either systemically or as a fumigant. The demeton had about as much effect upon the unsprayed portions of the trees as the parathion did upon the sprayed. Systemic action would probably be much greater early in the season. Within the sprayed area the two heaviest demeton treatments appeared to be about equal.

In January a few fruit buds were secured from the untreated trees and from those sprayed with 1 pint of demeton. The mites were found to be congregated between the bud scales rather than within the buds themselves. It appeared that about half the mites were on the rather bald outer surface of the bud scales, where they were much easier to count than when hidden in the hairy inner surface. Counts of mites found on the outer surfaces of bud scales from the untreated trees averaged 575 per bud as compared with 2 per bud from the demeton-treated trees. These results supported the data in table

1. This therefore appears to be a practical method of comparing mite populations. This orchard was thoroughly sprayed with lime-sulfur at dormant strength before further counts were made.

Early in the spring of 1953 six trees were sprayed with 50 per cent demeton at 1 pint per 100 gallons in each of two young orchards, and similarly infested trees were marked as checks. Little further spread was noted even in the checks until late July or early August. At that time damage became apparent in several young orchards and in a number of the older ones, even in some that had received dormant or delayed dormant sprays, which were expected to control the blister mites. Tests were made on Bartlett pears in three young orchards and two mature ones as soon as the fruit could be removed—late August and early September this year. It was noted that migration to the buds had begun, but the populations there were still low. A 21 per cent demeton formulation was used at 2 pints per 100 gallons. In two of the young orchards 25 per cent parathion was also used at 2 pounds per 100 gallons. In one mature orchard the owner applied lime-sulfur at 4 gallons per 100. Some leaf burn resulted from the lime-sulfur and leaf drop may have been speeded, but little if any real damage resulted so late in the season.

Both the parathion and the lime-sulfur reduced mite populations, as shown by counts in fruit and terminal buds in November (Table 2). Few dead mites were found within the buds receiving either treatment, and it may be that the materials did not penetrate either the blisters or the buds appreciably but killed the mites as they tried to migrate from the blisters to the buds. Extensive bud examination showed that, although occasional mites survived the demeton treatments, bud populations were lower than at the time of spray application.

Mite populations varied greatly from bud to bud even in the untreated buds. The variation was much greater in the trees treated with demeton in April 1953 at Helmich's orchard. Apparently in the late summer, as the effect of the treatment wore off, the extremely sparse population became completely unrestrained and large numbers developed in certain leaves although there were no mites at all in many of them. Predaceous mites were found in the buds from the untreated trees, but none in those from the demeton-treated ones. The percentage of the buds examined in which no mites were seen may be a better measure than the average number of mites per bud.

These tests indicate that demeton will reach the mites within the leaf and probably within the bud in lethal amounts, that either parathion or lime-sulfur will kill large numbers of mites as they migrate from leaf to bud, and that unrestrained development may appear here and there several months after treatment. Apparently demeton and similar systemic insecticides have a place in control practices for the pear leaf blister mite on young nonbearing trees, or on trees from which the fruit has been harvested.

Table 1.—Counts of blisters on leaves from sprayed and unsprayed portions of pear trees to determine condition of pear leaf blister mites. Yakima, Wash., 1952.

Treatment (amount per 100 Gallons)	Position of of Leaves on Tree[1]	Blisters Inactive	Blisters Dead
Check	Upper half	4	0
	Lower half	18	0
Demeton (42%):			
½ pt.	Unsprayed	22	3
	Sprayed	59	26
1 pt.	Unsprayed	26	12
	Sprayed	45	51
2 pt.	Unsprayed	36	22
	Sprayed	60	37
Parathion (15%) 1 lb.	Unsprayed	5	0
	Sprayed	44	4

[1] 100 blisters examined in each position on tree.

Table 2.—Pear leaf blister mites found in fruit and terminal buds of Bartlett pear trees in November following spring or early fall sprays. Yakima, Wash., 1953.

Orchard	Check		Demeton		Other Treatments	
	Number of Mites per Bud	Per Cent of Buds without Mites	Number of Mites per Bud	Per Cent of Buds without Mites	Number of Mites per Bud	Per Cent of Buds without Mites
	Spring treatment					
Helmich	33.5	7	86.5	33		
Mankle	114.4	5	112.4	24		
	Fall treatment					
					Lime-sulfur	
Weber[1]	41.7	12	0	100	3.2	79
Erickson	171.8	4	0.5	77		
					Parathion	
Green	19.0	14	0.2	92	3.9	42
Livingston	3.0	38	0.2	87	0.3	78
Fisher[1]	11.5	24	0	98		

[1] Bearing trees; the trees in the other orchards were nonbearing.

Tests of the Dielectric Treatment of Cotton Seed for Destroying Pink Bollworms

W. L. Lowry and A. J. Chapman, *Entomology Research Branch, Agr. Res. Serv.;* F. T. Wratten,[1] *Biological Sciences Branch, Agr. Mktg. Serv.,* and J. P. Hollingsworth, *Agricultural Engineering Research Branch, Agr. Res. Serv., U.S.D.A.*[2]

A well-recognized characteristic of the pink bollworm, *Pectinophora gossypiella* (Saund.), is its ability to survive in a quiescent stage for long periods of time under different climatic conditions. In most places where the pink bollworm occurs, resting larvae remain inside the cotton seed between growing seasons. These long-cycle larvae have been known to remain alive in seed for 2 years or longer (Loftin *et al.* 1921).

The ability of larvae to survive in cotton seed for long periods is probably responsible for the spread of this pest to nearly all the important cotton-growing areas If cotton seeds containing live larvae are transported to areas where this pest does not occur, a new infestation is likely to result. Untreated seed in an infested area, if carried over from one season to the next, can also increase pink bollworm numbers. Cotton-seed sterilization is therefore an important phase of pink bollworm control.

In one method of seed sterilization the seed is heated to a minimum of 150° F. for 30 seconds or longer. Fumigation with methyl bromide is also a method of killing larvae in the seed (Curl & White 1952). If properly applied, these control measures are generally satisfactory. However, there is a need for more efficient, uniform, and less expensive methods of destroying live larvae in seed. Experiments to test the usefulness of dielectric treatment for this purpose were conducted in 1952.

The dielectric heating apparatus consists of two conducting parallel plates, or electrodes, separated by a nonconducting material such as rubber, air, wood, or plastic, called a dielectric. If an alternating current is applied to the electrodes, the charged particles present in the dielectric will be alternately attracted and repelled. Generally this results in a torque, or twist, of these charged particles. If the torques are rapidly reversed, friction among these particles causes internal heating. The rate of heat development depends upon (a) the nonconductivity of the dielectric, (b) the difference in voltage between the two electrodes, (c) the frequency of alternation, and (e) the shape of the plates and their distance apart.

Materials and Methods.—The dielectric heater used was a General Electric model 4HD382, Plastic Preheater, which has a rated output of 3 kilowatts at a fixed frequency of 40 megacycles. The heater operates on 230-volt, 60 cycle, single-phase alternating current, and requires an input of 6.5 kilovolt-amperes. Two 160-cc. plastic boxes containing ginned cotton seed were placed, one above the other, between the electrodes. Preliminary tests had indicated this to be the most efficient arrangement of samples. It had also been found that treatments for 5 to 30 seconds at gradients between 1250 and 3000 volts per inch would possibly cover the effective range for sterilizing ginned cotton-seed.

Forty-gram lots of the seed infested with approximately 225 larvae were placed in the plastic boxes. Most treatments were replicated several times, and more than 200 lots were treated. Because of the large number of samples and the necessity of examining each individual seed, approximately 3 weeks were required to complete the examinations. To compensate for larval mortality that might occur in the interim, representative samples from the different treatments were examined as the work progressed. Each seed was cut open, and the numbers of both live and dead larvae were recorded. The percentages of larval survival were calculated by Abbott's formula.

Standard methods were used in tests to determine the effect of dielectric treatment on seed germination and analysis

[1] With the former Bureau of Plant Industry, Soils, and Agricultural Engineering.

[2] A cooperative project between the U. S. Department of Agriculture and the Texas Agricultural Experiment Station. Leo H. Soderholm, of the former Bureau of Plant Industry, Soils, and Agricultural Engineering, contributed valuable advice in planning the experiment. W. R. Cowley, of the Texas Agricultural Experiment Station at Weslaco, provided the facilities for the tests, and Jack L. Hubbard, also of the Weslaco station, conducted germination tests. Carl M. Lyman, Texas A. and M. College, made chemical analyses of treated seed. The General Electric Company furnished most of the equipment, including the dielectric heater.

for possible changes in chemical composition of the seed.

RESULTS.—The relationship between pink bollworm survival, the period of exposure, and the final temperature of the seed is shown in table 1. Complete kill was effected at final temperatures ranging from 161 to 173° F. produced by 1300, 1430, 1570, and 1780 volts per inch with exposure periods of 29, 19, 16, and 14 seconds, respectively. When the same voltage gradients were used with slightly shorter exposures there was some survival, and in additional tests the survival increased as the exposure time decreased. There was also some survival at temperatures ranging from 166 to 174°F. produced by voltage gradients of 2180, 2300, and 2400 with exposures of 12, 10, and 8.5 seconds, respectively.

Chemical analysis indicated that free fatty acids were not increased in seed exposed to voltage gradients of 2160, 1880, and 1760 for 20, 30, and 35 seconds, with consequent temperatures ranging from 153 to 175°F. The same treatments did not appear to affect germination of the seed, but the temperatures were about the maximum that could be tolerated for practical use in seed sterilization.

DISCUSSION.—These experiments indicate that dielectric treatment is simply a method of killing larvae by heat. The rate of heating increases with the voltage gradient; consequently the exposure time may be reduced. Survival is influenced by both the final temperature and the exposure time. Thus certain temperatures with relatively long exposures cause total kill, while the same or slightly higher temperatures with reduced exposure time permit some larvae to survive.

In the course of these experiments it was noted that arcing sometimes occurred when foreign materials such as burs, stems, and leaves were present in the seed. Under these conditions it would probably be inadvisable to use gradients in excess of 1250 volts per inch because of fire hazard. Thus a longer exposure time would be required to reach a temperature that would kill all the larvae.

Table 1.—Pink bollworm survival in cottonseed receiving dielectric treatments.

GRADIENT (VOLTS PER INCH)	EXPOSURE (SECONDS)	AVERAGE FINAL TEMPERATURE (° F.)	NUMBER OF LARVAE	PER CENT SURVIVAL
1300	29	173	315	0
	26	146	219	0.7
	23	147	232	1.4
	20	138	250	3.2
1430	19	167	186	0
	17	158	237	3.8
	15	143	229	7.0
1570	16	161	227	0
	14	155	247	1.9
	12	144	240	9.3
	10	135	221	49.6
1780	14	165	239	0
	11.5	151	239	4.0
	9	138	258	33.3
	7	130	219	94.4
2040	14	172	191	0
	12	160	205	3.9
	10	145	204	7.8
	8	134	166	70.9
2180	12	174	203	0.8
	11	168	192	0.8
	9	152	217	8.8
	7	135	208	57.3
2300	10	168	211	1.5
	8	150	240	10.6
	6	136	198	41.0
2400	8.5	166	215	1.5
	7	150	217	18.3
	5.5	136	210	47.7
2480	6.5	144	228	11.2
	5	133	197	54.1

SUMMARY.—Preliminary experiments with dielectric treatment to kill pink bollworms, *Pectinophora gossypiella* (Saund.), in cotton seed showed that survival is related to voltage gradient, exposure time, and final temperature of the seed mass. Field intensities of 1300 to 2040 volts per inch, with exposure times of 14 to 29 seconds, resulting in final temperatures of 161 to 173° F. caused complete kill. Such treatments did not appear to affect germination or chemical composition of the seed, but there was a fire hazard at such high voltage gradients.

LITERATURE CITED

Curl, L. F., and R. W. White. 1952. The pink bollworm. *In* Insects, U. S. Dept. Agr. Yearbook 1952, pp. 505–11.

Loftin, U. C., K. B. McKinney, and W. K. Hanson. 1921. Report on investigations of the pink bollworm of cotton in Mexico. U. S. Dept. Agr. Bull. 918.

Subunits of Sample for Estimating Aphid Abundance on Potatoes

W. A. SHANDS,[1] G. W. SIMPSON,[2] and L. B. REED[1,3]

Several methods have been described for estimating aphid abundance on potato plants. In most of them the aphids are counted while they are on the leaves. Davies (1932, 1934), Davies & Whitehead (1935, 1938), and Whitehead *et al.* (1932) initially made counts on 100 leaves in each field, one leaf from a plant, at various places on the plants, and expressed populations as the average total number of aphids per leaf, the number of each species of aphid on 100 leaves, the per cent of leaves infested, and the per cent of plants infested. Later they limited counts to 100 randomly located lower leaves in each field, and expressed populations as the number of aphids on 100 leaves. Still later counts were made on three leaves per plant, but the location of the leaves and the method of computing for that procedure were not indicated. Apparently Davies (1939) finally decided that 100 lower leaves in each field would give an adequate estimate of aphid population for his purpose.

Simpson (1932) made counts of aphids on three leaves per plant—one being taken at the base, another at the middle, and one at the top of the plant including the blossom. In later work (1940) he continued to use a stratified method of sampling—a top, middle, and bottom leaf from each sample plant. One hundred sample plants per field were considered adequate for an estimate of aphid population, and the population was in terms of the average number of aphids per 100 leaves. The sample plants were randomly located by a screen-grid method. Other workers have also employed a stratified method of sampling for aphids on potatoes. Broadbent (1948) and Bradley (1952) mentioned some of these and contrasted several methods for expressing aphid populations.

Shands & Simpson (1950, 1952) devised a procedure for measuring aphid populations on field-growing potato plants in which three subunits of sample are used. The basic unit of sample is a hill of potatoes. The unit is modified as the season advances to include only three whole leaves or smaller subunits of the same three leaves. Briefly, the sampling procedure consists in recording by species and form all aphids found on all leaves in the hill until the plants are about 8 inches tall. For larger plants, depending upon the numbers of aphids, field counts are made on (*a*) a randomly located leaf arising from the main axis within each of the top, middle, and bottom thirds of the plant's height; (*b*) only the terminal and two basal leaflets of each of these three leaves; or (*c*) only one-half of each of these leaflets. Leaves of less than about $1\frac{3}{4}$ inches in over-all length in the terminal leaf cluster are excluded. Where subunits of sample are used, aphid populations are expressed as the number per unit on the basis of three whole leaves per plant. Factors are used for converting counts involving leaflets and half-leaflets to the three-whole-leaf basis. The purpose of this paper is to give the basis for these samples and these conversion factors.

PROCEDURE.—In 1941 and 1942 records were made in several fields near Presque Isle, Maine, to show by species and leaflet position all wingless aphids on one leaf in each of the three strata of the plants. Winged aphids were not considered in this study. Leaflets were assigned numbers from 1 to 7, beginning with the basal leaflet on the left side of the rachis and going in a clockwise direction. Sample plants were randomly located in each field by a screen-grid method. The fields ranged from about 1 to 5 acres in size, but the sampling within each field was confined to a square area of about 1 acre. The data for each field were grouped into 10 subsamples of 10 plants each. Several varieties of potatoes were represented in the counts.

The species ratio, or the per cent of aphids that were of a given species, was used in studying the relative efficiency of the different types of samples. All per-

[1] Agr. Res. Serv., Entomology Research Branch, U.S.D.A.
[2] Maine Agricultural Experiment Station.
[3] J. M. Williams assisted in this work in 1941 and 1942, and M. F. McGlauflin and Pauline M. Stuart (Mrs. Eddie Ghazaleh) in 1942.

Table 1.—Per cent distribution of the wingless forms of three species of aphids on the leaves of potato plants in 1941.

APHID	TOP	MIDDLE	BOTTOM
Buckthorn	1	19	80
Green peach	6	20	74
Potato	14	28	58
All three species	6	20	74

centages given are true percentages calculated as weighted means. In the statistical analyses, however, no weights were employed.

Only three species of aphids were included in this study—the buckthorn aphid *Aphis abbreviata* Patch, the green peach aphid, *Myzus persicae* (Sulz.), and and the potato aphid, *Macrosiphum solanifolii* (Ashm.). The foxglove aphid, *Myzus solani* (Kltb.) has been common on potatoes in Maine during recent years, but it did not occur in the fields used for these studies.

RESULTS IN 1941.—Table 1 shows the vertical distribution of the aphids on plants from three counts in each of three fields on August 28, September 4, and September 9, 1941. All three species increased in abundance from top to bottom leaves. The potato aphid had the highest percentage on the top leaves and the buckthorn aphid the lowest, emphasizing the necessity for stratified samples. Therefore, in all subsequent study the data for each sample plant were combined. It should be pointed out that this is not the typical distribution of the potato aphid when the potato plants are in flower, but probably it is for the periods before and after this period. During that time, expecially if populations are large, an appreciable percentage of the total potato aphid population is found on the inflorescence.

Table 2.—Per cent of aphids of each species as obtained by different leaflet samples in 1941.

TYPE OF SAMPLE	APHID	PER CENT OF TOTAL	COEFFICIENT OF CORRELATION WITH ESTIMATE FROM WHOLE LEAVES
Whole leaves	Buckthorn	23	—
	Green peach	57	—
	Potato	20	—
Leaflet 4	Buckthorn	25	0.951
	Green peach	54	.905
	Potato	21	.906
Leaflets 1 and 7	Buckthorn	20	.887
	Green peach	61	.886
	Potato	19	.830
Leaflets 1, 4, and 7	Buckthorn	23	.982
	Green peach	58	.952
	Potato	19	.952

Table 3.—Species ratios of aphids as calculated from whole-leaf and leaflet samples in 1942.

APHID	WHOLE LEAVES	LEAFLETS 1, 4, AND 7	COEFFICIENT OF CORRELATION
Buckthorn	57	55	0.974
Green peach	33	33	.991
Potato	10	12	.996

Species ratios were obtained for each 10-plant subsample and for each type of sampling (Table 2). Those obtained by counting the aphids on only leaflets 1, 4, and 7 were highly correlated with those obtained by counting the aphids on all the leaflets, the correlation coefficient being above 0.95 for each species. Leaflet 4 provided a better estimate than leaflets 1 and 7. Analysis of variance disclosed that data for leaflet 4 alone resulted in a significant overestimate of buckthorn aphid relative abundance, while data for leaflets 1 and 7 gave a highly significant overestimate for the green peach aphid. In other words, buckthorn aphids comprised an unduly large part of the total population on terminal leaflets, and green peach were aphids relatively more abundant on the two opposing basal leaflets. No significant difference in distribution of the potato aphid was found between whole leaves and leaflets or leaflet combinations.

RESULTS IN 1942.—Counts of aphids similar to those in 1941 were made in eight fields from July 20 to August 24 in 1942. Table 3 shows there was very close agreement between whole leaves and a combination of leaflets 1, 4, and 7 on the same leaves in the percentage of total population comprised by each species. The leaflet combination resulted in a slightly lower estimate for relative abundance of the buckthorn aphid and slightly higher for the potato aphid. The differ-

Table 4.—Percentages of standard error of the mean numbers of wingless aphids of each species by subunits of two sizes in 1942.

APHID	WHOLE LEAVES	LEAFLETS 1, 4, AND 7
Buckthorn	6.25	5.96
Green peach	12.76	12.50
Potato	6.50	6.76

ences, however, were not significant at the 5 per cent level.

Table 4 shows that for each species the standard error of mean numbers of aphids per plant for counts involving leaflets 1, 4, and 7 was about the same as for those involving whole leaves, indicating that both subunits of sample result in aphid population estimates of about the same degree of accuracy.

DISCUSSION OF RESULTS.—A consideration of chief importance in planning field experiments with aphids on potatoes is the increase in time required to make counts as the season advances, especially when populations become large. The results of this study provide a basis for reducing, without impairment of accuracy, the size of the subunit of sample from three whole leaves per plant to leaflets 1, 4 and 7 of three leaves per plant. Use of the smaller subunit not only reduced by 57.1 per cent the number of leaflets to observe, but it also reduced by 61.9 per cent the number of aphids to count, thus effecting an appreciable saving in both time and effort of the observer.

Application of the results of the study has been carried one step further. When aphid populations become very large, the subunit of sample is reduced to one-half of each of leaflets 1, 4, and 7 on a leaf in each of the three standard positions. A half-leaflet is the entire area on one side of the leaflet midrib. The sides of the leaflets for aphid counts are alternated between plants. Therefore only half as much leaf area and half as many aphids are involved in this procedure as when whole leaflets 1, 4, and 7 constitute the subunit.

Use of the reduced size of sample subunits does not prevent expressing aphid populations in terms of the average number per three whole leaves per plant. This can be done by dividing the number of aphids by 38.1 and multiplying by 100 when the subunit is the 1-4-7 leaflet combination, or by using 19.05 as the factor when half-leaflets of this combination is the subunit.

The question arises as to when the size of the subunit can be reduced safely. Table 5 shows considerable variation between fields in the aphid populations on the plants used in the study. To determine the subunit to use one should observe the numbers of aphids of all species on several randomly located plants outside the sample portion of the plot. Leaflets 1, 4, and 7 should be used when there are at least 100 aphids on three whole leaves per plant, and half-leaflets when the number approaches 500. The size of the subunit is increased on a like basis as populations decrease toward the end of the season.

Adoption of the two smaller subunits has been a distinct aid in the field work with aphids on potatoes in Maine. In fact, it has been possible to conduct more field experiments, particularly in plots where insecticides are not applied. Further, with a known amount of field assistance it is possible to plan and carry through the experiments irrespective of the ultimate maximum size of the aphid population and, in most instances, without reduction in the number of sample units per plot.

The foxglove aphid was not on potato plants used in the study in 1941 and 1942, but it has been present annually since then. Because observations have not suggested that this aphid may exhibit distribution characteristics differing appreciably from those of the three species found in this study, the subunits of sample described are assumed to be applicable to this species as well.

Table 5.—Wingless aphid populations on three whole leaves per plant in three fields in 1941 and eight fields in 1942.

APHID	1941		1942	
	Range	Mean	Range	Mean
Buckthorn	1– 21	10	8–347	143
Green peach	6– 82	35	8–274	84
Potato	1– 6	4	4– 74	24
All three species	13–100	52	48–414	252

SUMMARY.—The basis is given for two subunits of sample in making field populations counts of wingless aphids on potato plants. One subunit consists of the terminal and two opposite basal leaflets of three leaves per sample plant, one randomly located within the top of the plant, one in the middle, and one in the bottom. The other subunit consists of one-half of each of these leaflets.

The use of the leaflet sample involved only 42.9 per cent as many leaflets to observe and 38.1 per cent as many aphids to count as the use of the whole-leaf sample.

It is assumed that equally satisfactory estimates of very large aphid populations can be obtained by making counts of the aphids on only one-half of each sample leaflet, and provided that on alternate plants the right and left halves, respectively, of the leaflets are examined. Appropriate conversion factors were developed for expressing the population estimates on a whole-leaf basis.

LITERATURE CITED

Bradley, R. H. E. 1952. Methods of recording aphid (Homoptera: Aphididae) populations on potatoes and the distribution of species on the plant. Canad. Ent. **84:** 93–102.

Broadbent, L. 1948. Methods of recording aphid populations for use in research on potato virus diseases. Ann. Appl. Biol. **35:** 551–66.

Davies, W. Maldwyn. 1932. Ecological studies on aphides infesting the potato crop. Bull. Ent. Res. **23:** 525–48.

Davies, W. Maldwyn. 1934. Studies on aphides infesting the potato crop. II Aphis survey: its bearing upon the selection of districts for seed potato production. Ann. Appl. Biol. **21:** 283–99.

Davies, W. Maldwyn. 1939. Studies no aphides infesting the potato crop. VII Report on a survey of the aphis population of potatoes in selected districts in Scotland (25 July–6 August 1936). Ann. Appl. Biol. **26:** 116–34.

Davies, W. Maldwyn, and T. Whitehead. 1935. Studies on aphides infesting the potato crop. IV Notes on the migration and condition of alate *Myzus persicae* Sulz. Ann. Appl. Biol. **22:** 549–56.

Davies, W. Maldwyn, and T. Whitehead. 1938. Studies on aphides infesting the potato crop. VI Aphis infestation of isolated plants. Ann. Appl. Biol. **25:** 122–42.

Shands, W. A., and G. W. Simpson. 1950. Control of aphids on potatoes with DDT when used with fungicides. Maine Agr. Expt. Sta. Bul. 480.

Shands, W. A., and G. W. Simpson. 1952. Survey methods: Aphid populations on potatoes. U. S.D.A. Bur. Ent. & Pl. Quar. Coop. Econ. Ins. Rept. **3:** 181–2.

Simpson, G. W. 1932. Spraying and dusting experiments for the control of potato aphids. JOUR. ECON. ENT. **25:** 634–9.

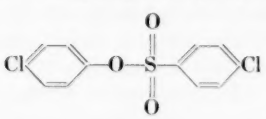
Simpson, G. W. 1940. Aphids and their relation to the field transmission of potato virus diseases in northeastern Maine. Maine Agr. Expt. Sta. Bul. **403:** 189–305.

Whitehead, T., J. F. Currie, and W. M. Davies. 1932. Virus diseases in relation to commercial seed production—with a study of the aphis population at selected centres. Ann. Appl. Biol. **19:** 529–49.

Residues of *p*-Chlorophenyl-*p*-chlorobenzenesulfonate (*Compound K-6451*) on and in Lemons and Oranges[1,2]

F. A. GUNTHER and L. R. JEPPSON,[3] *University of California Citrus Experiment Station, Riverside*

In purified form the acaricide *p*-chlorophenyl-*p*-chlorobenzenesulfonate possesses the following physical properties:



Molecular weight: 303.2

λ max. (95 per cent ethyl alcohol): 229.5, 256.5, 264. 5, 267.5, 276. 5 mμ

λ max. (2,2,4-trimethylpentane): 228.5, 256.5, 265, 268.5, 276 mμ

A_1 (95 per cent ethyl alcohol): 797 at 276.5 mμ, 18,350 at 229.5 mμ

A_1 (2,2,4-trimethylpentane): 740 at 276 mμ, 20,400 at 228.5 mμ

Carefully purified *p*-chlorophenyl-*p*-chlorobenzensulfonate exists as odorless, colorless, chunky prisms melting at 85.8°–86.8° C. (from medium boiling petroleum ether). It is stable under ordinary conditions, but is readily hydrolyzed in solution by strong alkali.

This material is used in the control of the citrus red mite, *Metatetrancychus citri* (McG.). Formulated products containing this acaricide are usually referred to as "*Ovotran*" formulations containing the technical grade material "*K-6451.*" Information regarding the penetration and persistence of residues of this acaricide is

[1] Paper No. 821, University of California Citrus Experiment Station, Riverside, California.

[2] Paper presented in part before the Pesticides Subdivision, Division of Agricultural and Food Chemistry, 121st Meeting, American Chemical Society, Milwaukee, Wisconsin, 1952.

[3] Grateful acknowledgment for laboratory and field assistance is accorded J. H. Barkley, R. C. Blinn, J. O. Complin, J. M. Dunham, W. J. Hanson, M. J. Jesser, R. J. Krantz, and A. H. Kutschinski. Some financial and laboratory assistance was provided by The Dow Chemical Company.

reported in this paper. In addition, the analytical method used in determining the residues is described.

MATERIALS AND METHODS.—The acaricide *p*-chlorophenyl-*p*-chlorobenzenesulfonate (*K-6451*) was applied as a 50 per cent wettable formulation (*Ovotran*) in a water spray with conventional high-pressure equipment and manually operated spray guns. Spray was applied at the rate of 1,000 gallons per acre of mature lemon trees and 1,500 gallons per acre of mature orange trees. Residue samples of mature fruit were collected 4 to 6 feet from the ground from the periphery of the trees, with one fruit from each quadrant of each of eight trees. Duplicate samples were picked by different individuals but from the same eight trees. To avoid handling, the sample fruits were dropped into wide-mouthed, 3-gallon glass jars as they were clipped from the trees. The jars were capped and placed immediately in storage at 10° C. Sample fruits were processed and analyzed within 2 days.

Three types of residues were determined, namely, the ABC type, peel and pulp type, and juice type. The ABC residues are obtained by a technique proposed by Carman & Gunther (1951)[4] and detailed by Gunther & Blinn (1954), and involving the arbitrary segregation of migrating residues into (A) extracuticular residue or residue adhering to the wax layer (the true surface residue); (B) cuticular residue or residue embedded within or dissolved in the wax layer, and (C) subcuticular residue or residue penetrated below the wax layer (this category may be subdivided and more precisely designated botanically if desired, as pericarpal residue, albedo residue, etc.).

For peel and pulp residues, the washed fruits were peeled by means of a buttonhook peeler in such a manner that the albedo layer was removed from the fruit, yet the fruit itself was not punctured. The entire mass of peel was diced and pooled, and 1-pound subsamples were withdrawn by quartering. Each 1-pound subsample was minced in the presence of medium boiling petroleum ether, then equilibrated on a tumbling machine for 1 hour. The peeled fruits from above were pierced equatorially twice with a No. 15 cork borer with sawtooth edge. From the resulting plugs of pulp the two ends were carefully cut, and the pulp obtained in this way was pooled and subsampled by quarters to suitable aliquots. These aliquots were minced, tumbled with the petroleum ether for 5 minutes, then allowed to stand at 10° C. with occasional shaking for 48 hours.

Juice samples, from commercial-type juice or from our own power juicer, were extracted with five successive 200-ml. portions of the petroleum ether per kilogram of juice.

Since all these extraction operations (except the "B" treatment) are equilibration treatments, the amounts of solvents added originally were carefully measured. Thus is was not necessary to secure quantitative separation of emulsions nor to be concerned about hold-up of solvent with coarse marcs. After equilibration, as much of the solvent as could conveniently be recovered was decanted through Sharkskin filter paper into a bottle with screw cap. Filled bottles were topped first with a layer of aluminum foil then with 3 layers of No. 300 MST cellophane, capped tightly and stored at 10° C. for at least 2 days. This storage period afforded a clear supernatant solution.

ANALYTICAL DETAILS.—The analytical method used (Gunther *et al.* 1952)[5] was a modification of that presented by Kutschinski & Luce (1952) and briefly described by Gunther & Blinn (1954). In this method the *p*-chlorophenyl-*p*-chlorobenzenesulfonate in filtered petroleum ether stipping solution is simultaneously evaporatively concentrated and hydrolyzed to sodium *p*-chlorophenate. Interfering oils and waxes are removed from this hydrolysate by steam distillation in special apparatus. The *p*-chlorophenol is then steam-distilled from the hydrolysate after acidification and determined colorimetrically with 4-aminoantipyrine in the presence of potassium ferricyanide (λ max. 510 mμ). The characterization of the color body has not been made (Emerson 1943, Emerson & Kelly 1948, Gottlieb & Marsh 1946).

REAGENTS AND APPARATUS.—The reagents used were the following:

[4] Carman, G. E., and F. A. Gunther. 1951. Factors related to the differentiation of extrasurface and subsurface residues. Paper presented at the 35th Annual Meeting, Pacific Branch, American Association of Economic Entomologists, Seattle, Washington. (Unpublished.)

[5] Gunther, F. A., L. R. Jeppson, R. C. Blinn, A. H. Kutschinski, R. J. Krantz, and J. H. Barkley. 1952. Ovotran residues in citrus fruits. Paper presented at the 121st Meeting of the American Chemical Society, Milwaukee, Wisconsin. (Unpublished.)

p-chlorophenyl-*p*-chlorobenzenesulfonate, m.p. 85.8–86.8° C., from medium-boiling petroleum ether.

Antifoam A (Dow-Corning) as foam depressant.

Potassium hydroxide, 0.1 *N* solution in ethyl alcohol.

Sulfuric acid, 18 *N* solution.

Triethanolamine, 1.0 *M* and 0.1 *M* solutions (Erwin 1953).[8]

4-Aminoantipyrine, 2 per cent aqueous solution, prepared fresh every week from material recrystallized several times from dilute ethyl alcohol.

Potassium ferricyanide, 8 per cent solution, prepared fresh every week.

Special apparatus included the source of dry steam, the steam-distillation apparatus shown in figure 1, and a Beckman model B spectrophotometer with both 1- and 5-cm. cells.

PROCEDURE.—An aliquot (200 to 300 ml.) of the filtered petroleum ether stripping solution, 10 ml. of 0.1 *N* potassium hydroxide solution in ethyl alcohol, and two 5-mm. glass balls were placed in a Kuderna-Danish type evaporative concentrator. After about 20 minutes on the steam bath the solvent volume was reduced to approximately 3 ml., and the hydrolysis to sodium *p*-chlorophenate was complete.

After removal of the Snyder column, the flask and receiving tube were transferred to the steam-distillation unit shown in figure 1. If more than a few milligrams of fruit oils and waxes were present at this stage, approximately 10 mg. of foam depressant was added.[6] Steam was then passed rapidly through the apparatus to remove fruit oils, waxes, and other steam-distillable materials until approximately 50 ml. of distillate had been collected, or until the volume of the oily layer in the distillate did not increase. Steam condensing within the apparatus usually brought the liquid level up into the flask; if there was more condensate than could be accommodated in the lower one-third of the "ball" of the flask, external heat was used to reduce the volume.

With the steam vented temporarily, 15 ml. of 18 *N* sulfuric acid solution was added through the top cap of the distillation apparatus. Steam was again passed through the apparatus but at a rate slow enough just to prevent bumping when a Bunsen burner was lighted at full heat below the receiver tube. From 80 to 90 ml. of distillate was collected in a 100-ml. volumetric flask. It was necessary to supply most of the required heat from the burner, and the final volume in the receiver tube and flask assembly was not more than 25 ml.[7] The final distillate was adjusted to 100 ml. with distilled water.

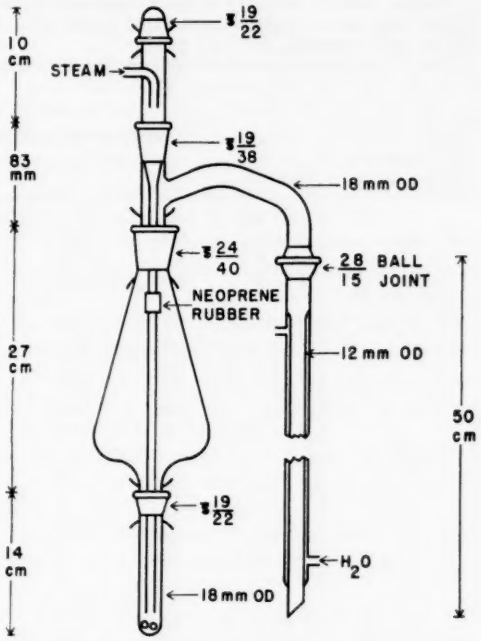


FIG. 1.—Unit steam-distillation apparatus. The receiver tube and flask assembly are from a Kuderna-Danish type evaporative concentrator (Gunther & Blinn 1954). A bank of four of these units is convenient for large numbers of samples.

Exactly 20 ml. of the distillate was pipetted into a 25-ml. volumetric flask, and 2.5 ml. of 1.0 *M* triethanolamine solution (Erwin 1953)[8] was added.[9] Next 0.5 ml. of the 4-aminoantipyrine solution was added with thorough mixing by shaking. Then 0.25 ml. of potassium ferricyanide solution was added with mixing by shaking. The sample was adjusted to volume with 0.1 *M* triethanolamine solution, and the transmittancy at 510 mμ[10] was deter-

[6] This was done conveniently by smearing the foam depressant on the lower end of the steam inlet tube.

[7] If more than this volume was retained, the recovery of the *p*-chlorophenol was not quantitative.

[8] Erwin, W. 1953. Improvements in the methods for Ovotran and genite analysis. Paper presented at First Annual Meeting, Pacific Branch, Entomological Society of America, Lake Tahoe, California. (Unpublished.)

[9] This provided a pH of 10.6 in the final solution, and since the pH markedly influenced the final intensity of color, the same pH was used throughout. R. L. Metcalf (personal communication) has used with success a 0.1 *M* Veronal (sodium diethylbarbiturate) solution to give a pH of 9.5 in this procedure.

[10] The color was fully developed after 15 minutes and was stable for at least 1 hour. A 20-ml. aliquot of the final distillate was used for the development and determination of color; this represented only one-fifth of the amount of *p*-chloropnenyl-*p*-chlorobenzenesulfonate present in the aliquot of extract used. For quantities of *p*-chlorophenol less than 50 micrograms in the final solution, the final distillate was made strongly alkaline and concentrated to a suitably smaller volume.

Table 1.—*ABC* residues of p-chlorophenyl-p-chlorobenzenesulfonate (*K-6451*) from fruit of mature lemon and navel orange trees after application of spray containing 1 pound of a wettable powder, 50 per cent material, per 100 gallons.[1]

Days After Treatment	Sample	Residue						
		Micrograms/Aliquot			Parts per Million[2]			
		A	B	C	A	B	C	Total[3]
				Lemons				
3	1+2	880	375	1110	0.9	0.7	1.5	
	3+4	820	340	1440	1.2	0.4	1.8	3.0
	Check	290	trace	0	0.3	<0.1	0.0	
7	1	770	570	480	1.8	0.7	1.0	
	2	880	130	420	2.2	0.2	0.9	
	3	670	50	480	1.0	0.1	2.1	
	4	690	210	480	1.1	0.3	2.9	2.6
	Check	200	130	120	0.3	0.2	0.5	
	Check	130	180	160	0.2	0.2	0.5	
14	1	450	0	630	0.8	0.0	1.1	
	2	460	0	280	0.8	0.0	2.1	
	3	270	0	475	0.5	0.0	0.6	
	4	300	0	500	0.5	0.0	1.2	1.7
	Check	180	0	0	0.3	0.0	0.0	
	Check	0	0	0	0.0	0.0	0.0	
28	1+2	420	140	260	0.3	0.1	0.6	
	3+4	280	140	250	0.2	0.1	0.3	0.5
	Check	130	120	140	0.1	0.1	0.1	
58	1	80	285	185	0.2	0.3	0.2	
	2	0	55	180	0.0	0.0	0.2	
	3	0	0	225	0.0	0.0	0.5	0.3
	4	310	0	145	0.5	0.0	0.3	
	Check	40	0	0	0.1	0.1	0.0	
				Navel oranges				
0	1	1750	135	835	1.1	0.1	1.4	
	2	1250	trace	497	1.2	0.1	1.1	2.5
	Check	0	0	0	0.0	0.0	0.0	
19	1	157	216	295	1.2	0.6	1.5	
	2	101	342	187	0.8	0.1	1.9	2.8
	Check	49	0	0	0.3	0.0	0.0	

[1] *A*, extracuticular; *B*, cuticular; *C*, subcuticular.
[2] Based on weight of whole fruit.
[3] Average of *A*+*B*+*C* values, corrected for check *A*+*B*+*C*.

mined after 15 minutes, the instrument being set with a field control which had been subjected to the exact cleanup and analytical procedures used for the residue sample.

Calibration Curve.—A standard calibration curve was prepared from pure *p*-chlorophenyl-*p*-chlorobenzenesulfonate by using exactly the same cleanup and analytical procedures as were used for the residue samples.

Interference.—Many quinones, phenols, and phenolic esters interfere.

Alkaline hydrolysis of citrus extractives, followed by acidification and steam distillation in the usual manner (Kutschinski & Luce 1952), afforded cloudy yellow-to-orange distillates not amenable to evaluation as to *p*-chlorophenol content. Unsuccessful attempts to eliminate these interferences without losses of *p*-chlorophenol included hydrolysis with alkaline hydrogen peroxide solution; with alkaline permanganate solution; with potassium hydroxide or sodium hydroxide in refluxing methyl, ethyl, isopropyl, amyl, and octyl alcohols and cyclohexanol; and with sodium shot in the above refluxing alcohols. Successful measures included the present steam distillation of the alkaline hydrolysis mixture prior to acidification and steam distillation of the desired phenol; incubation, for 8 hours at 40° C., of the yellow, cloudy

Table 2.—Peel and pulp residues of *K-6451* from fruit of mature lemon treees after application of sprays containing 0.75 pound of a wettable powder, 50 per cent material, per 100 gallons.

DAYS AFTER TREATMENT	TREATMENT	RESIDUE			
		Micrograms/Aliquot		Net Parts per Million[1]	
		Peel	Pulp	Peel	Pulp
0	*K-6451*	100	trace	6.4	0.0
	Check	trace	0		
4	*K-6451*	630	0	3.8	0.0
	Check	0	0		
8	*K-6451*	500	0	3.4	—
	Check	280	0		
16	*K-6451*	800	250	3.1	0.4
	Check	150	98		
32	*K-6451*	430	190	2.0	—
	Check	110	—		
60	*K-6451*	220	0	0.5	0.0
	Check	170	0		

[1] Based on weight of specified portion of fruit only. Average of all check samples used in calculating net parts per million.

distillate in 5 per cent potassium hydroxide solution; and incubation, for 2 hours at 50° C., of the yellow, cloudy distillate in a 0.02 per cent suspension of papain. However, the recommended procedure was most adaptable to unitization of apparatus.

SENSITIVITY.—This method is capable of detecting 10 micrograms of *p*-chlorophenyl-*p*-chlorobenzenesulfonate in the presence of the extractives from 1 pound of citrus peel, with an error of approximately 20 per cent. In a standard calibration curve, deviation from Beers' law occurs below about the 50-microgram level of *p*-chlorophenol per sample.

Effects of pH, quantities of reagents, temperature, and age of colored solution were reported by Ettinger *et al.* (1951) while the present work was in progress. Our results are in essential agreement with theirs except that for *p*-chlorophenol we found maximum intensity of color developed within 8 minutes, with 1.5 per cent fading (relative) after 1 hour at constant temperature and in the dark.

RESULTS.—Detailed residue data for p-chlorophenyl-*p*-chlorobenzenesulfonate applied to lemons are shown in tables 1, 2, and 3, and applied to navel and Valencia oranges in tables 1 and 3. Table 3 also includes residue information for juice prepared in the commercial manner from field-treated mature lemons.

DISCUSSION.—It must be emphasized the colorimetric method as here utilized will not distinguish between intact *p*-chlorophenyl-*p*-chlorobenzenesulfonate and the possible *in situ* hydrolysis product *p*-chlorophenol.

When the data in tables 1 and 2 are plotted as in figure 2, the typical attenuation behavior or residues of organic insecticides is demonstrated. From such curves it may be calculated that the half-life value (Gunther & Blinn 1954) for residues of this acaricide applied to citrus fruits is approximately 10 days.

When the data in table 1 are reproduced in graphical form, as in figure 3, the approximate picture of rates and extents of penetration may be adduced. The $A+B+C$ (actual) curve in this figure is the

Table 3.—Residues of *K-6451* in peel, pulp, and juice of Valencia oranges from mature trees after spray application of 1 pound of a wettable powder per 100 gallons (determined by two different methods).

TREATMENT	DAYS AFTER TREATMENT	RESIDUE							
		Micrograms/Aliquot				Parts per Million[1]			
				Juice[2]				Juice[2]	
		Peel	Pulp	Hot-pack	Frozen	Peel	Pulp	Hot-pack	Frozen
Colorimetric Method									
K-6451	14	1,000	0.0	0.0	0.0	2.3	0.0	0.0	0.0
Check	14	—	0.0	0.0	0.0	—	0.0	0.0	0.0
Organic Chlorine Method[3]									
K-6451	14	—	776	403	226	—	4.0	0.7	0.4
Check	14	—	206[4]	145	226	—	0.5[4]	0.3	0.4

[1] Based on weight of specified portion of fruit only.
[2] Processed in commercial manner by Sunkist Growers Inc., Ontario, California.
[3] Organic chlorine only, but calculated as *p*-chlorophenyl-*p*-chlorobenzenesulfonate, from a combustion technique (see Gunther & Blinn 1954).
[4] Average of four samples.

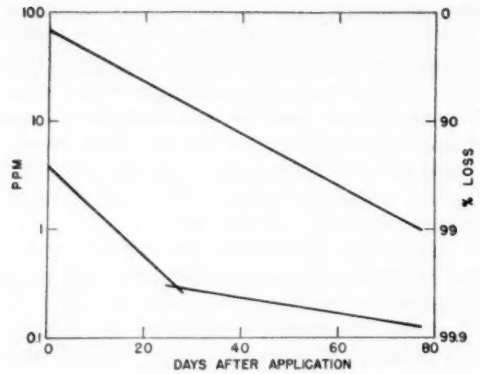


FIG. 2.—Curvilinear representation of the degradation and persistence behavior of *p*-chlorophenyl-*p*-chlorobenzenesulfonate residues on and in orange peel (bottom curve), as contrasted with the behavior of DDT residues on and in orange leaves (upper curve).

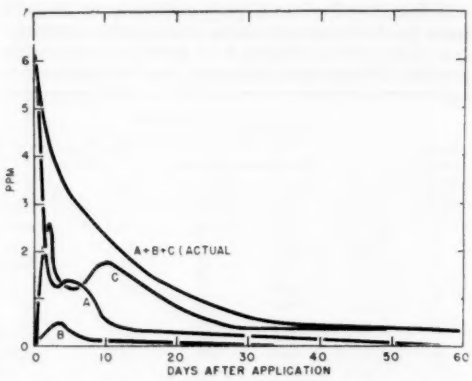


FIG. 3.—Penetration behavior of residues of *p*-chlorophenyl-*p*-chlorobenzenesulfonate in the peel of treated lemons. The $A+B+C$ (actual) curve is the smoothed curve summed from curves *A*, *B*, and *C*.

typical residue disappearance or attenuation curve, obtained by adding curves *A*, *B*, and *C*. Since three separate stripping operations were involved in each such point summation, the smoothness of the resulting curve indicates that the component residue data are valid and reliable. Immediately after application, therefore, the acaricide migrates very quickly into the cuticular waxes to the extent of about 75 per cent loss from the surface within 2 to 3 days. The concentration within the wax layer reaches a maximum level within 4 to 5 days, then seems to attain equilibrium proportions as the acaricide traverses this layer possibly in both directions. In the meantime the acaricide has penetrated into the peel, reaching a maximum level within 9 to 11 days. The appearance of the secondary *A* maximum demonstrates that some of the penetrated material reissues toward the fruit surface. After about 15 days all three types of residues have essentially stabilized in rates and directions of migration.

The pronounced rate of disappearance of the *C* residue may be attributable, in part at least, to metabolic attacks within the peel. Many of the samples were also analyzed in parallel by a total organic chlorine method involving combustion to chloride ion (see Gunther & Blinn 1954). Residues by this combustion technique were generally higher than by the colorimetric method, which also suggests that some of the dissipated *p*-chlorophenyl-*p*-chlorobenzenesulfonate was metabolized to nonphenolic products.

SUMMARY.—The largest portion of the residues of the acaricide *p*-chlorophenyl-*p*-chlorobenzenesulfonate on and in mature oranges and lemons at any time shortly after application is subcuticular, and thus is not available for removal by usual packing-house treatments. Apparently, little if any of the acaricide penetrates the juice of either fruit. The half-life value for this acaricide in citrus peel is approximately 10 days. Details of the analytical method utilized in determination of residues are presented and discussed.

LITERATURE CITED

Emerson, E. H. 1943. The condensation of aminoantipyrene. II. A new color test for phenolic compounds. Jour. Org. Chem. **8:** 417–28.

Emerson, E. H., and K. Kelly. 1948. The condensation of aminoantipyrene. VI. A study of the effect of excess base of the reaction of aminoantipyrene with phenolic compounds in the presence of oxidizing agents. Jour. Org. Chem. **13:** 532–4.

Ettinger, M. B., C. C. Ruchhoft, and R. J. Lishka. 1951. Sensitive 4-aminoantipyrene method for phenolic compounds. Analyt. Chem. **23:** 1783–8.

Gottlieb, S., and P. B. Marsh. 1946. Quantitative determination of phenolic fungicides. Ind. Eng. Chem., Analyt. Ed. **18:** 16–9.

Gunther, F. A., and R. C. Blinn. 1954. Analysis of Insecticides and Acaricides. (See chapters 7 and 15.) Interscience Publishers, New York. (In press)

Kutschinski, A. H., and E. N. Luce. 1952. Determination of *p*-chlorophenyl-*p*-chlorobenzenesulfonate in spray residues on fresh fruits. Analyt. Chem. **24:** 1188–90.

Harvest Residues of Apparent Dieldrin in Peel and Juice of Navel Oranges[1,2]

F. A. GUNTHER, J. H. BARKLEY, and W. H. EWART, *University of California Citrus Experiment Station, Riverside*

Ewart *et al.* (1952) have published analytical data for harvest residues of dieldrin in lemons and navel oranges from simulated commercial type treatments. At the level of 0.5 pound of actual insecticide per application per acre, their data indicated a range of dieldrin values of from 0.0 to 1.3 p.p.m. in the peel and from 0.0 to 0.5 p.p.m. in the pulp or juice of the fruits; however, their control samples of fruit not treated with dieldrin afforded apparent residue values ranging from 0.0 to 0.6 p.p.m. in the peel and from 0.0 to 0.4 p.p.m. in the pulp or juice. Although with treated fruit the net average was found to be only 0.3 p.p.m. of apparent dieldrin in the orange peel and 0.0 p.p.m. in the pulp or juice over amounts found in untreated fruit, it was felt desirable to reinvestigate the magnitudes of these residues with analytical methods more sensitive and more reliable than were formerly used, with particular attention to increasing the reliability of background values of apparent dieldrin. Thus, out of the total of 144 determinations,[3] Ewart *et al.* (1952) reported 81 values of 0.0 p.p.m. of dieldrin. Out of the total of 56 per cent of these zero values, less than half originated with the control or untreated check samples. The occurrence of such a large proportion of zero values among the replicates of the treated samples suggests the positive residue values may have resulted from laboratory or manipulative contamination, and suggests that demonstrable dieldrin may not have been present at all.

In their previous investigation, Ewart *et al.* washed the stripping solutions free of inorganic chlorides, evaporated then burned the organic residues in a stream of oxygen, and determined the chloride ion concentration in the combustion products argentometrically. In the present effort, added sensitivity and reliability were achieved by controlled wet oxidation and extraction of oxidation products prior to combustion and by the use of a new direct potentiometric method for the determination of chloride ion.

Table 1.—Summary of field treatments involved in residue evaluations.

Code	1952 Date of Application	Dosage and Formulation of Dieldrin/100 Gals. of Spray	Gals. of Spray/Acre/Application
(1) Z-53-13 & Z-53-14	May 12	1 lb. 50%[1]	100
Z-53-15 to Z-53-22, inclusive	May 12	635 ml. 18½%[2]	200
(2) Z-53-23	May 12	635 ml. 18½%[2]	200
	Aug. 18	1270 ml. 18½%[2]	100
Z-53-24 to Z-53-32, inclusive	May 12	½ lb. 50%[1]	200
	Aug. 18	1 lb. 50%[1]	100
(3) Z-53-2 to Z-53-11, inclusive	Control[3]	—	—

[1] Wettable powder.
[2] Emulsifiable concentrate containing 1½ lbs. of dieldrin/gallon.
[3] Double-size samples were collected to provide for the fortification data.

In complicance with the above reasoning, the following additional harvest-residue determinations have now been made:

1. On navel oranges from 10 plots treated with dieldrin in May, 1952 when the fruits were a centimeter in diameter.
2. On navel oranges from 10 plots treated as above plus a treatment in August, 1952 when the fruits were still green in color but nearly fully sized.
3. On navel oranges from 10 plots not treated with dieldrin or any other halogen-containing insecticide in 1952.
4. On navel oranges from 10 plots as in item 3 above, but fortified with known amounts of dieldrin during the "stripping solution" stage of the processing operations.

FIELD APPLICATIONS AND SAMPLES.—In table 1 are listed codification, dates of applications and treatments applied to the navel oranges in the field. Individual field samples consisted of 64 mature oranges each, with 8 fruits from each of 8 trees collected from the quarters of a peripheral band about chest height around each tree. Only outside fruits were used. All samples were collected on January 15, 1953, placed in cold storage, and then processed between February 2 and February 13, 1953.

[1] Paper No. 820, University of California Citrus Experiment Station, Riverside, California.
[2] Grateful acknowledgment is made for field and laboratory assistance from R. B. Carlson, H. S. Elmer, J. H. Kizer, J. D. Paschke, M. G. Sprott, G. B. Wacker, and J. P. Wolfe III.
[3] All the values reported by Ewart *et al.* (1952) in their tables 6 and 7 were the averages of triplicated field samples.

Table 2.—Efficiency of combined cleanup, combustion, and determinative procedures.

Sample	Purified Dieldrin,[1] mg.		Per Cent Recovery
	Added[2]	Recovered	
Stripping solvent[3] alone	None	Not more than 0.020	—
Orange peel extractives[4]	None	Not more than 0.100[5]	—
	0.105, 0.110	0.103, 0.111	99, 100
	0.538, 0.542	0.534, 0.538	99, 99
	1.060, 1.060	0.987, 1.004	93, 95
	1.060, 1.060	0.999, 1.025	94, 97
Orange juice extractives[4]	None	Not more than 0.100[5]	—
	0.117, 0.070	0.115, 0.071	99, 100
	1.060, 1.060	1.000, 1.030	94, 98

[1] Melting point 175°–6° C.
[2] By aliquotting a standard solution in medium boiling petroleum ether.
[3] Liter quantities.
[4] From 1-kilogram quantities of fruit part.
[5] Subtracted from fortified samples below.

PROCESSING METHOD.—Each orange was peeled, and the peel from a sample was composited, diced, and a 1000-gram portion selected by quartering. The sample of peel was minced (Gunther 1949) for 5 minutes with 2 liters of medium boiling petroleum ether, and then equilibrated for 30 minutes on a drum-tumbler stripping machine (Gunther & Blinn 1950). After being filtered through Sharkskin filter paper, the resulting stripping solution was stored at 10° C. in a bottle with screw cap and aluminum foil cap liner.

Each peeled orange was pierced antipodally twice with a No. 15 cork borer. The albedo-containing ends of each juice plug so obtained were cut off, and all plugs from a sample were combined. A 1000-gram portion of plugs was minced for 2 minutes with 2 liters of medium boiling petroleum ether, then stored at 10° C. in the sealed mincing container for 2 days. The resulting petroleum ether strippling solution was decanted through Sharkskin filter paper into storage bottles and stored as above.

CLEANUP METHOD.—All stripping solutions were extracted three times with 300-milliliter portions of distilled water, then two times with chloride-free distilled water.

Each such extracted solution was evaporatively concentrated in the usual manner (Gunther & Blinn 1954) to 50 milliliters, then evaporated to "waxy" dryness (to remove excess limonene) over 24 hours with a gentle stream of charcoal-filtered, dry air at ambient temperatures. Approximately 250 milliliters of acetone, purified by being refluxed and fractionated over excess powdered potassium permanganate, was added. Then 4 grams of powdered sodium bicarbonate (2 grams for juice samples) and 3 grams (1.5 grams for juice samples) of 120-mesh powdered potassium permanganate were added, and the mixture was refluxed for 2 hours. After being cooled, the oxidation mixture was evaporatively concentrated as above to 100 milliliters, acidified with 30 milliliters of 3*N* sulfuric acid solution, and carefully decolorized with saturated sodium bisulfite solution. The resulting mixture was then diluted to 500 milliliters with distilled water and carefully extracted twice with 250-milliliter portions of medium boiling petroleum ether. The two organic extracts were combined and washed successively twice with 50-milliliter portions of 0.5*N* sulfuric acid solution, twice with 50-milliliter portions of saturated sodium bicarbonate solution, and three times with 100-milliliter portions of chloride-free distilled water. Two drops of white oil were added to each sample at this stage.

COMBUSTION METHOD.—After being evaporatively concentrated to a dry residue in the quartz capsule of a Kuderna-Danish apparatus (Gunther & Blinn 1954), each sample was burned at 1000° C. in a stream of oxygen in a dual quartz tube combustion apparatus. Effluent gases were collected in 20 milliliters of chloride-free 0.2 per cent sodium carbonate solution.

CHLORIDE DETERMINATION.—To each scrubbing solution was added 2 milliliters of chloride-free 16*N* nitric acid solution, and it was diluted to exactly 50 milliliters with chloride-free distilled water. Chloride ion contents were determined on triplicate portions of each sample at 41° C. by the direct potentiometric method for chloride ion (Helmkamp *et al.* 1954). This method involves a silver-silver chloride *vs.* calomel electrode system with measurement of potential by means of a Beckman Model GS pH meter, and is reproducibly sensitive to 0.02 p.p.m. of chloride ion in 3 milliliters or less of sample solution within the range 0.02 to 10,000 p.p.m. of chloride ion without concentration or dilution steps.

PROCEDURES VALIDATION.—In table 2 are collated typical blank and recovery data for combined cleanup, combustion, and determinative methods. Samples

were burned in units of 16 to 20. Prior to the burning of each such unit, two reagent blanks and two fortified control samples were burned to establish combustion blanks and efficiency. Individual samples were then corrected for the appropriate tube blank, e.g., 0.09 p.p.m. of chloride ion for quartz-tube "A" for that unit of 8 to 10 samples subsequently burned in tube "A." Thus, in the present series of dieldrin-treated oranges, there were 44 such tube blanks, 6 solvent blanks, and 10 fortification controls.

RESIDUE DATA.—In table 3 are listed the detailed residue data. Each p.p.m. value represents the average of three chloride-ion determinations on portions of that sample after combustion; all such determinations agreed within 0.02 millivolt on the scale of the pH meter used (Helmkamp *et al.* 1954).

RESULTS AND CONCLUSIONS.—Comparisons among the analyses of treated and untreated fruit (Table 3) demonstrate that dieldrin was not present in measurable amounts in the peel or pulp of the fruit from plots treated in May (Code Z-53-13 to Z-53-22, inclusive). This was probably to be expected since the fruit was only "pea-size" at the time of treatment. With the plots receiving treatments in May and also in August (Code Z-53-23 to Z-53-32, inclusive), an average net of 0.08 p.p.m. of apparent dieldrin was found in the peel and less than 0.01 p.p.m. was found in the juice, based upon the weight of the fruit part involved and evaluated in terms of kilogram samples replicated 10 times. Orange peel comprises approximately one-sixth the weight of the whole fruit.

Table 3.—Details of harvest residue data for navel oranges treated in the field with dieldrin.

CODE		APPARENT DIELDRIN,[1] P.P.M. Peel	Juice
(1) (May treatment)	Z-53-13	0.08	0.05
	14	.18	.05
	15	.22	.05
	16	.13	—
	17	.14	.04
	18	.10	.03
	19	.15	.00
	20	.15	.05
	21	.28	.10
	22	.13	.04
	Av.	0.159	0.046
(2) (May & Aug. treatments)	Z-53-23	0.27	0.13
	24	.37	.08
	25	.23	.08
	26	.25	.08
	27	.20	.03
	28	.18	.03
	29	.27	.01
	30	.34	.02
	31	.18	.03
	32	.25	.02
	Av.	0.254	0.057
(3) (untreated)	Z-53- 2	0.16	0.05
	3	.19	.05
	4	.18	.07
	5	.21	.04
	6	.16	.03
	7	.16	.02
	8	.20	.04
	9	.14	.03
	10	.13	.05
	11	.19	.06
	Av.	0.172	0.049

[1] Based on fresh weight of part concerned.

LITERATURE CITED

Ewart, W. H., F. A. Gunther, J. H. Barkley, and H. S. Elmer. 1952. Control of citrus thrips with dieldrin. JOUR. ECON. ENT. 45(4): 578–93.

Gunther, F. A. 1949. Apparatus for mincing biological materials. Anal. Chem. 21: 748–9.

Gunther, F. A., and R. C. Blinn. 1950. Mass-production techniques for estimation of parathion residues. Advances in Chem. Series 1: 72–87.

Gunther, F. A., and R. C. Blinn. 1954. Analysis of insecticides and acaricides. Interscience Publishers, New York. (In press)

Helmkamp, G. K., F. A. Gunther, J. P. Wolfe, III, and J. E. Leonard. 1954. Direct potentiometric method for chloride ion applied to residues of chlorinated insecticides. Jour. Agr. Food Chem. 2: 836–9.

Some Ecological Aspects of the Resistance of Crop Plants to Insects[1]

REGINALD H. PAINTER, *Kansas State College, Manhattan*

The use of insect resistance in crop plants has been successful as a control measure for a number of insects. A few examples of this use of insect resistance in plants as an insect control measure are given here. The spring wheat varieties Rescue and Chinook have been bred and released in Canada as a means of combating the wheat stem sawfly. Rescue is grown on several million acres in Canada and North-Central United States. The wheats Poso 42 and Big Club 43 have replaced hessian fly susceptible wheats in Central California and the Bureau of Entomology project located there was discontinued because of the scarcity of hessian fly for study.

The hessian fly resistant wheat variety Pawnee was released to Nebraska farmers in 1942 and to Kansas and Oklahoma farmers in 1943. By 1946, it became the leading wheat in acreage in Kansas and by 1949 the leading wheat in acreage in the United States. Largely because of the use of this variety. the population of hessian fly in central Kansas has been reduced to the point where it is seriously interfering with breeding of fly-resistant wheats. Pawnee wheat is less resistant in eastern Kansas where Ponca, released in 1951, can be grown. Ponca has been resistant to hessian fly wherever tested. Cartwright and his co-workers in Indiana have fly-resistant soft wheat varieties well along toward release to farmers in that area (Cartwright & Jones 1952).

In the South, considerable progress has been made toward breeding sweet corn which is resistant to the corn earworm (Walter 1951, Yarnell 1952, Smith 1953). Within the next few years, corn hybrids carrying some resistance to the first generation of the European corn borer should be available—or are now available in Ohio, Indiana, Minnesota, and elsewhere from the work of the U. S. Department of Agriculture and state entomologists and associated corn breeders (Dicke 1951, Holdaway 1951, Neiswander 1952). Through studies in Oklahoma, varieties of combine sorghums, such as Combine Kafir 44–14 and Redlan, resistant to chinch bugs, have become available (Packard & Martin 1952). Advances also are being made toward producing greenbug resistant barleys (Fadely 1953).

DEFINITION.—Resistance may be defined as the effects of heritable characters of a plant that influence the amount of damage done by the insect. In common with other genetic characters, resistance is inherited as the tendency of plant and insect to react in a certain way in a particular environment. If some feature of the environment is changed, the resistance reaction may or may not be changed. Hence, ecology is basically important in a study of resistance. The subject matter of this discussion may be considered under two principal headings (1) ecological factors that modify the expression of resistance and (2) ecological factors that influence the effectiveness of resistance as an insect control measure.

Analysis of examples of resistance show that it is made up of one or more of three groups of factors: preference or nonpreference, antibiosis, and tolerance (Painter 1951). Ecological conditions under which these plant-insect relationships occur may modify the expression of resistance toward either greater or less resistance. Ecological factors may affect the insects, the plant, or the insect-plant interaction. Tolerance, which is primarily a plant reaction, appears to be influenced by ecological conditions to a greater extent than the other two groups of characteristics—preference and antibiosis. Corn varieties tolerant to chinch bugs in Illinois have been less tolerant in Kansas, apparently because of their greater susceptibility to drought and the similarity of drought and chinch bug damage.

EFFECT OF PHYSICAL, BIOTIC, AND EDAPHIC FACTORS ON THE EXPRESSION OF GENES FOR RESISTANCE.—Various physical factors affect the expression of genes for resistance. Under high tempera-

[1] Invitation paper presented at the Annual Meeting of the Entomological Society of America held at Los Angeles, Calif., December 7–10, 1953.

Contribution No. 627, Department of Entomology, Kansas Agricultural Experiment Station, Manhattan.

tures in the greenhouse (above 110° F.), the corn leaf aphid showed less discrimination among sorghum varieties. That is, the differences between resistant and susceptible varieties in respect to preference were smaller than at lower temperatures. The relative position of varieties with respect to resistance remained about the same, however. Pea aphid mortality on some resistant alfalfa plants was higher at moderate than at low temperatures, while on other resistant plants the mortality was high over a considerable range of temperatures.

About a half dozen genes or groups of genes are concerned in the resistance of various wheats to hessian fly (Shands & Cartwright 1953, Painter 1951). Resistance in all cases occurs because of the death of all or most of the young larvae which reach the usual feeding places on resistant wheats. The different resistant genes found in Marquillo and I11. 01W38, and in hybrids derived from these parents, are not as effective in causing death of larvae at higher temperatures in the green house. Resistant plants carrying Marquillo genes show this temporary "breakdown of resistance" to a greater extent than do plants with genes from I11. #1. In contrast, resistant plants carrying genes derived from the unnamed Durum P.I.94587, show a resistance that approaches immunity at all temperatures at which they have been tested.

Atmospheric humidity may influence preference of insects for particular hosts by indirectly affecting their olfactory response. Certain insects tend to aggregate through orthokinesis in areas of particular humidity. In this way the response to humidity tends to bring the insects in an area of contact with other stimuli from the host plants. The hessian fly female tends to lay more eggs at higher humidities. The small larvae also survive better so there are more individual insects to establish an infestation and to be resisted by the plant.

Many different biotic relationships may influence the expression of genes for resistance. Differences in resistance that are related to the age of the plant are known in connection with several cases of resistance. Corn plants generally show a high level of resistance to the European corn borer until the plants are about 2 feet high. In the same way, young corn plants are highly resistant to the corn leaf aphid, susceptible varieties not becoming susceptible until they are a few weeks old. In contrast, sorghum plants are susceptible to the corn leaf aphid from the seedling stage through maturity.

Infestations by the hessian fly on resistant wheat varieties deriving their resistance from Kawvale or Marquillo almost always have been higher in the spring, during the time of speedy growth, than in the fall, during slower growth. Infestation of resistant varieties has been especially high when the infestation occurred at high temperatures as well as when the stems were elongating rapidly.

Another interesting case of differences in age resistance is that of the chinch bug on sorghums. In general, small sorghum plants are less tolerant to chinch bugs than larger ones, but among the various varieties there is a wide difference in the effect of sorghum varieties on egg deposition, longevity, and rate of development of chinch bugs reared on these varieties. With some varieties, the effect on the biology of the chinch bugs when they feed on older plants is parallel to the effect when they feed on younger plants. In one sorghum variety, Feterita, the average number of eggs laid by the female on seedling plants is small, while the number laid on old plants is large (Dahms 1948). This variety, hence, behaves as a resistant variety in the seedling stage and as a susceptible variety when it is older. This peculiar situation is reflected in the fact that Feterita in the field appears to be more resistant some years than it does in other years.

Plant disease has been observed to affect the reaction of insects to particular varieties in several cases. Grasshoppers have been noted several times to feed to a greater extent on rust infected wheat. The Colorado potato beetle is said to prefer diseased potato plants over healthy ones. Yarwood *et al.* (1953) suggested that a preference for diseased plants may be related to differences in nutritive value. These biotic factors all influence the expression of genetic factors for resistance and susceptibility.

Entomologists have long observed that insects are affected in various ways by differences in the soil in its influence on plant growth. Generally it has been considered that vigorous plants or plants

growing in more fertile soil are attacked less, and damaged less by insects. Damage by the European corn borer is a conspicuous example of a plant-soil-insect relationship in which the reverse is true. In general, corn plants growing in more fertile soil are selected for oviposition by corn borer moths and usually the larvae thrive better on such plants.

In a review of edaphic relations to insect resistance, it was pointed out (Painter 1951) that "each species of insect and often each host-plant species or variety constitutes a separate problem." Probably also, each different type of soil constitutes a separate problem. During the last few years, a number of additional studies have been made on the effect of differences in soil on insects by way of their host plants (Arant & Calvin 1951, Barker & Tauber 1951a, 1951b, Eden 1953, Garman & Kennedy 1949, Hocking 1953, Neiswander *et al.* 1950, Rodriguez & Neiswander 1949, Smith & Northcott 1951, Smith & Harris 1952, Taylor *et al.* 1952). With some insects, no significant differences traceable to edaphic factors have been found. In other cases, highly significant differences have been found with insects feeding on plants growing in different levels of fertilizer elements. Tolerance, antibiosis, and preference, less commonly, have been involved to varying extents. Where information has been available, differences in infestation resulting from soil differences have been much less than differences resulting from resistant and susceptible varieties concerned. For the most part, these more recent studies tend to reinforce the conclusions reached earlier on the basis of scantier information.

So far as plant resistance is concerned, there may be two different classes of edaphic effects. In the first place, differences arising from soil treatments may be a source of variation in resistance from time to time and from place to place, thus affecting the expression of resistance. In contrast, these soil-plant-insect relationships may also involve a mechanism of resistance since certain species and varieties of plants when grown in the same kind of soil may differ through differing abilities of the varieties to utilize the chemical elements present in soil.

EFFECT OF ECOLOGICAL FACTORS ON THE POTENTIALITIES OF PLANT RESISTANCE AS AN INSECT CONTROL MEASURE.—A resistant plant variety with antibiotic qualities affects profoundly the fecundity of the insect that feeds upon it. Usually the larval or nymphal feeding period is lenghtened, the adult life shortened, and the number of young produced decreased. All of these effects influence the reproductive potential directly, upsetting the balance between reproductive potential and environmental resistance, and making the insect more vulnerable to other adverse effects of the environment. It is important to note that in contrast to insecticides, the effect of the resistant plant is continuing and cumulative, leading to progressive decrease in population in each generation if the insect were previously in balance with its environment. The longer feeding period exposes the insect to its parasitic and predaceous enemies for a longer time. Likewise, it is exposed for a longer time to diseases to which a changed physiology may make the insect more susceptible. The decreased reserve fat, such as occurs when the Colorado potato beetle feeds on resistant plants, leads to lessened capacity for successful hibernation. The effect of other unfavorable weather conditions may also be enhanced.

Adverse ecological conditions appear to have increased the value of the hessian fly resistant qualities of Pawnee in central Kansas. When the wheat variety Pawnee was first introduced, the fly was building up toward outbreak proportions under favorable weather conditions. Despite favorable weather for the insect, as the acreage of Pawnee increased, the fly population began to decrease (Painter 1951, table 5). Since 1948, in several seasons the weather has been unfavorable to the development of the insect while the acreage of Pawnee has remained fairly constant. The last two seasons, throughout central Kansas it was almost impossible to find any hessian fly even in the most favorable locations.

This effect of Pawnee wheat in reducing the hessian fly population appears far greater than could have been predicted on the basis of experimental nursery results. The explanation seems to lie in the cumulative and additive effects of the resistant variety coupled with unfavorable weather. In the hessian fly nurseries where Pawnee and other resistant wheat were studied, everything was done to make ecological conditions favorable to

the insect. The wheat was planted early; it was irrigated as needed; susceptible wheat was kept in the area all the year round; and new, heavily infested stubble brought in each year. Under such conditions, Pawnee has been about half as much infested as susceptible wheats. In farmers' fields since distribution, Pawnee has rarely attained such an infestation as had occurred in the nurseries and has usually had a much lower infestation even when weather conditions were favorable. With the dryer conditions of the last few years, the hessian fly population in central Kansas has dropped to the lowest level since the fly was introduced into the area in 1885. The hessian fly had survived dry conditions of earlier years because in some highly favorable areas small populations could always be found. It survived the early years of the distribution of the resistant variety, Pawnee, when weather conditions were favorable. But the partially resistant variety Pawnee, combined with unfavorable ecological conditions, has had a greater effect in lowering the hessian fly population than was expected.

Another interesting feature of the Pawnee-hessian fly situation has been that the biotype or population of fly able to feed on Pawnee has not increased as fast as expected with the widespread distribution of this variety. There is some evidence that the type of fly in eastern Kansas able to feed on Pawnee is not so well adapted to the drier conditions of central and western Kansas (Painter 1951). The association together of this physiological adaptation to a variety and an ecological adaptation to a moister area in the same biotype provides a tentative explanation for the limited increase of this population.

A partially resistant variety that has only a small effect on fecundity of an insect may have a large effect on the population of that insect when the resistant variety is grown on a large acreage. Similarly, a more susceptible variety than those currently grown may have the reverse effect. Both these results may be exaggerated by other favorable or unfavorable ecological conditions. Thus, there have been wide fluctuations of the European corn borer in both Ohio and Iowa during 1946 to 1951, but Neiswander (1952) would list the widespread use of resistant hybrids as one of the reasons the populations of this insect were only half as high in Ohio as in Iowa. In Iowa, there has not yet been time to develop adapted hybrids that are borer-resistant.

SUMMARY.—Resistance of crop plants to insects is inherited as the tendency of a variety to support a lower insect population or to be injured less under a given environmental condition. Hence, ecology is the background against which crop resistance to insects is developed. To a greater or less extent physical, biotic, and edaphic factors all affect the expression of genes for resistance.

Under some situations, ecological conditions unfavorable to the insect resisted has increased the value of resistance beyond that to be expected on the basis of cage and nursery studies.

LITERATURE CITED[2]

Arant, F. S., and Calvin M. Jones. 1951. Influence of lime and nitrogenous fertilizers on the population of greenbugs infesting oats. JOUR. ECON. ENT. **44**: 121–2.

Barker, J. S., and O. E. Tauber. 1951. Development of green peach aphid as affected by nutrient deficiencies in a host, Nasturtium. JOUR. ECON. ENT. **44**: 125.

Barker, J. S., and O. E. Tauber. 1951. Fecundity of and plant injury by the pea aphid as influenced by nutritional changes in the garden pea. JOUR. ECON. ENT. **44**: 1010–2.

Cartwright, W. B., and E. T. Jones. 1952. The hessian fly and how losses from it can be avoided. Farmers' Bul. **1627**.

Dahms, R. G. 1948. Effect of different varieties and ages of sorghum on the biology of the chinch bug. Jour. Agr. Res. **76**: 271–88.

Dicke, F. F. 1951. Breeding for corn borer resistance. N. Cent. States Branch Amer. Assoc. Econ. Ent. Proc. **6**: 89–90.

Eden, W. G. 1953. Effect of fertilizer on rice weevil damage to corn at harvest. JOUR. ECON. ENT. **46**: 509–10.

Fadely, D. D. 1953. The green bandit. Crops and Soils. **6**(3): 10–1.

Garman, Philip, and B. H. Kennedy. 1949. Effect of soil fertilization on the rate of reproduction of the two-spotted spider mite. JOUR. ECON. ENT. **42**: 157–8.

Hocking, B. 1953. Larval nutrition in *Agrotis orthogonia* Morr. (Lepidoptera: Phalaenidae). A new rearing method. Canad. Jour. Agr. Sci. **33**: 23–9.

[2] Further documentation will be found in Painter (1951).

Holdaway, F. G. 1951. Breeding corn for borer resistance in Minnesota. N. Cent. States Branch. Amer. Assoc. Econ. Ent. Proc. **6**: 90.
Neiswander, C. R. 1952. Fluctuations in corn borer population levels. N. Cent. States Branch Amer. Assoc. Econ. Ent. Proc. **7**: 58–61.
Neiswander, C. R., J. G. Rodriquez, and R. B. Neiswander. 1950. Natural and induced variations in two spotted spider mite populations. JOUR. ECON. ENT. **43**: 633–6.
Packard, C. M., and John H. Martin. Resistant crops, the ideal way. U. S. Dept. Agr. Yearbook. **1952**: 429–36.
Painter, Reginald H. 1951. Insect resistance in crop plants. New York. Macmillan. 520 p.
Painter, Reginald H. 1953. The role of nutritional factors in host plant selection. IX Int. Cong. Ent. **2**: 101–5.
Rodriquez, J. G., and R. B. Neiswander. 1949. The effect of soil soluble salts and cultural practices on mite populations on hothouse tomatoes. JOUR. ECON. ENT. **42**: 56–9.
Shands, R. G., and W. B. Cartwright. 1953. A fifth gene conditioning hessian fly response in common wheat. Agron. Jour. **45**: 302–7.
Smith, D. S., and F. E. Northcott. 1951. Effects on the grasshopper *Melanoplus mexicanus* (Sauss.) (Orthoptera; Acrididae), of varying the nitrogen content of its food plant. Canad. Jour. Zool. **29**: 297–304.
Smith, E. H., and R. W. Harris. 1952. Influence of tree vigor and winter injury on the lesser peach tree borer. JOUR. ECON. ENT. **45**: 607–10.
Smith, Glenn M. 1953. Release of white sweet corn inbreds 81–1 and 471–U6. Purdue Univ. Mimeo. BP-55.
Taylor, L. F., J. W. Apple, and K. C. Berger. 1952. Response of certain insects to plants grown on varying fertility levels. JOUR. ECON. ENT. **45**: 843–8.
Thorsteinson, A. J. 1953. The role of host selection in the ecology of phytophagous insects. Canad. Ent. **85**: 276–82.
Walter, E. V. 1951. The development of sweet corn varieties resistant to the earworm. N. Cent. States Branch Amer. Assoc. Econ. Ent. Proc. **6**: 13–4.
Yarnell, S. H. 1952. Breeding for resistance to the earworm in sweet corn. Amer. Soc. Hort. Sci. Proc. **60**: 379–86.
Yarwood, C. E., Alice P. Hall, and Marjorie M. Nelson. 1953. Nutritive value of rust-infected leaves. Science **117**: 326–7.

Effect of Certain Insecticides and Fungicides on Plant Emergence and Control of the Seed-Corn Maggot[1]

M. H. FROST, JR.,[2] L. D. ANDERSON,[2] and J. C. ELMORE[3]

Seed-corn maggots, *Hylemya cilicrura* (Rond.), as well as various fungus diseases attack sprouting seeds during late winter and early spring, particularly during periods of high humidity.

The seed-corn maggot is not a new pest, but only in the past 8 years have materials been developed which give control. Reid (1936) found that organic fertilizers increased the damage to seedlings. In 1940 he described the life history of this insect as it is found along the coastal plain of the South Atlantic States. Turner (1945) used methods of seed treatment with little success. The early use of lindane as a seed treatment was reported by Brooks & Anderson (1947). Ristich & Schwardt (1949) expanded upon the biology of the seed-corn maggot. In their discussion on controls they favored soil application of insecticides rather than seed treatment. The principal work in northern California has been done by Lange *et al.* (1951), who describe the successful control of maggots on Fordhook Concentrated Bush lima bean by seed treatment. This variety of lima bean was found to be very susceptible to insecticide injury. A treatment dosage of $\frac{1}{3}$ ounce of 75 per cent lindane, plus a suitable fungicide, per 100 pounds of large lima bean seed was suggested. Howe *et al.* (1952) describe experiments conducted in New York from 1947 through 1950. Reliable control was obtained with insecticide-fungicide combinations used as seed treatments. Either insecticide or fungicide used alone resulted in unsatisfactory stands. Seed treatments eliminated the need for planting lima beans during the limited "fly-free" period which occurs during mid-June in western New York. Elmore (1953) gives recent recommenda-

[1] Paper No. 824, University of California Citrus Experiment Station, Riverside, California.
[2] University of California Citrus Experiment Station, Riverside, California.
[3] U.S.D.A., Agr. Res. Serv., Entomology Research Branch, Whittier, California.

tions for maggot control in southern California.

The experiments reported in the present paper were designed to determine the effects of the insecticides dieldrin and lindane, and of certain fungicides, upon the emergence of seedlings of green peas, spinach, onion, cotton, and nine varieties of cucurbits.

MATERIALS AND METHODS.—All the experiments reported were conducted in the field. With the exception of one planting of spinach on the C. Borchard Ranch in Orange County, all the plots were located at the University of California Citrus Experiment Station (CES) at Riverside.

Three different dosages of each insecticide were used, with and without a fungicide. The materials were applied both as a dry powder and as a slurry. The required amounts of the toxicants were weighed, added to an appropriate quantity of seed, and mixed by tumbling in a glass jar. For the slurry treatments, water was added at the rate of 2 per cent of the weight of the seed being treated.

For the cotton, peas, onions, and nine varieties of cucurbits, 100 seeds were selected for each treatment. Spinach seed was weighed in lots of 2.1 grams (average, 206 seeds) per treatment. All treatments were replicated five times.

Whenever possible, the soil was preirrigated and disked to attract seed-corn maggot flies. The seed bed was then prepared in a conventional manner. Planting was accomplished by means of a push-type hand planter,[4] a 1-inch tube and 8-inch funnel being substituted at waist level for the seed box. The seed was dropped into the funnel at regular intervals while the planter was pushed at an even pace.

Seeds of nine varieties of cucurbits were treated, namely, those of pumpkin (Small Sugar No. 861), zucchini squash, cucumber (Marketeer), watermelon (Klondike R7), muskmelon (Imperial 45), crookneck (Golden) summer squash, Banana Pink (winter) squash, Royal Acorn squash, and Early White Bush (summer) squash. For these seeds lindane (75 per cent) or dieldrin (75 per cent) at $\frac{1}{3}$, $\frac{2}{3}$, and $1\frac{1}{2}$ ounces per 100 pounds of seed was used with a fungicide (thiram, 75 per cent) or with an inert carrier to determine the effects of the insecticide upon seed-corn maggot and possible phytotoxicity to the germinating seeds. Thiram (75 per cent) was used on all seeds with the exception of crookneck squash seed at $1\frac{1}{2}$ and 3 ounces in combination with the insecticides and at 3 ounces alone, per 100 pounds of seed, to show its effect upon diseases causing seed decay. The crookneck squash seed was treated with thiram (50 per cent) at 4 ounces. The same combinations of insecticides and fungicide were used in slurry treatments and in dust treatments for comparison. Since the dusts did not adhere properly to the smooth seed coats of Banana Pink, Early White Bush, and Royal Acorn squash, only the slurry treatment was used for these seeds. The percentage emergence of seedlings after the various treatments is shown in table 1.

Acid-delinted and machine-delinted cotton seed[5] (Acala 4-42) was given the same treatments as the cucurbits, except that dieldrin was omitted and *Ceresan M*[6] was substituted for thiram. The fungicide alone was used dry on the machine-delinted seed and as a slurry on the acid-delinted seed. The percentage emergence of seedlings after the various treatments is shown in table 2.

Seeds of green pea, onion, and spinach were treated with lindane or dieldrin, with and without thiram. The insecticides were used at $\frac{1}{4}$, $\frac{1}{2}$, and $1\frac{1}{2}$ ounces, and thiram at 3 ounces, per 100 pounds of seed. Dry treatments, only, were used on these seeds as the seed coats of some of the varieties were too rough for satisfactory use of slurry treatments. The percentage emergence of seedlings after the various treatments is shown in table 3.

RESULTS.—The seed-corn maggot is a difficult insect to work with in the field, as infestations often do not materialize in the experimental plots. Nevertheless, useful information on the effect of the insecticides and fungicides upon plant emergence was obtained from all the plots.

Pumpkin.—Emergence counts of pumpkin seed (Table 1) showed no significant differences. Seed-corn maggots were not present in the plots. Seeds not

[4] *Planet Jr.*, manufactured by S. L. Allen & Company, Inc., 3483 N. Fifth Street, Philadelphia 40, Pa.

[5] Mr. J. C. Elmore did not participate in the cotton seed experiments.

[6] Ethyl mercury *p*-toluene sulfonanilide; manufactured by Semesan Division, E. I. du Pont de Nemours & Co. (Inc.), Wilmington, Delaware.

Table 1.—Percentage emergence of cucurbit plants after treatment of seeds with various dosages of lindane and dieldrin with and without thiram, Riverside, California, 1953.[1]

Material[2]	Dosage (Ounces)	Pumpkin	Cucumber	Watermelon	Muskmelon	Squash: Zucchini	Squash: Crookneck[3]	Squash: Banana Pink	Squash: Royal Acorn	Squash: Early White Bush	Mean
Slurry-Treated											
Lindane +thiram	⅓ 1½	76.2	70.4	33.8	53.2	—	—	70.4	63.2	81.2	
Lindane +thiram	⅔ 3	72.2	72.4	41.2	54.0	75.4	—	76.0	69.2	77.8	
Lindane +thiram	1⅓ 3	72.0	76.0	49.8	48.8	72.8	—	70.0	59.0	73.8	
Average		*73.5*	*72.9*	*41.6*	*52.0*	*74.1*	—	*72.1*	*63.8*	*77.6*	65.9
Dieldrin +thiram	⅓ 1½	70.6	84.6	36.2	58.8	—	—	—	—	—	
Dieldrin +thiram	⅔ 3	72.0	75.6	44.8	68.0	74.8	—	—	—	—	
Dieldrin +thiram	1⅓ 3	64.4	78.6	45.0	71.6	74.6	—	—	—	—	
Average		*69.0*	*79.6*	*42.0*	*66.1*	*74.7*	—	—	—	—	66.3
Lindane +inert	⅓ 1½	—	—	—	—	—	—	55.0	61.6	67.4	
Lindane +inert	⅔ 3	—	—	—	—	—	—	58.0	62.2	70.4	
Lindane +inert	1⅓ 3	—	—	—	—	—	—	55.2	61.2	58.8	
Average		—	—	—	—	—	—	*56.1*	*61.7*	*65.5*	61.1
Thiram	3	—	—	—	—	—	—	75.8	74.8	82.8	77.8
Dust-Treated											
Lindane +thiram	⅓ 1½	74.0	69.4	23.4	55.6	—	—	—	—	—	
Lindane +thiram	⅔ 3	75.8	72.6	34.2	61.6	76.4	28.2	—	—	—	
Lindane +thiram	1⅓ 3	72.0	80.2	28.2	57.2	72.4	36.4	—	—	—	
Average		*73.9*	*74.1*	*28.6*	*58.1*	*74.4*	*32.3*	—	—	—	56.9
Dieldrin +thiram	⅓ 1½	73.8	81.4	33.6	67.6	—	—	—	—	—	
Dieldrin +thiram	⅔ 3	67.8	79.2	36.4	46.4	72.2	49.4	—	—	—	
Dieldrin +thiram	1⅓ 3	69.8	82.2	37.2	47.6	70.4	32.6	—	—	—	
Average		*70.5*	*80.9*	*35.7*	*53.9*	*71.3*	*41.0*	—	—	—	58.9
Lindane +inert	⅔ 3	78.0	45.6	12.6	29.2	58.8	18.8	—	—	—	
Lindane +inert	1⅓ 3	81.4	53.8	24.2	28.4	59.4	18.6	—	—	—	
Average		*79.7*	*49.7*	*18.4*	*28.8*	*59.1*	*18.7*	—	—	—	42.4
Dieldrin +inert	⅔ 3	72.4	52.4	10.0	34.0	54.6	15.2	—	—	—	
Dieldrin +inert	1⅓ 3	80.6	47.2	7.0	43.6	55.2	19.0	—	—	—	
Average		*76.5*	*49.8*	*8.5*	*38.8*	*54.9*	*17.1*	—	—	—	40.9
Lindane +thiram +inert[4]	⅔	—	—	—	—	—	34.2	—	—	—	
Thiram	3	73.4	76.2	22.8	54.4	74.6	21.2	—	—	—	53.8
Untreated	—	78.0	48.4	13.0	34.8	63.6	6.0	56.4	57.2	74.8	48.0
L.S.D. at 5% level		n.s.	14.1	12.8	13.0	8.0	11.52	13.80	n.s.	n.s.	

[1] Each treatment consisted of 100 seeds replicated 5 times.
[2] Unless otherwise specified, lindane, dieldrin, and thiram were used at 75%; the inert material was pyrophyllite.
[3] Unless otherwise noted, for tests with crookneck squash thiram 50%, at 4 ounces, was used in place of thiram 75% at 3 ounces.
[4] A proprietary seed-treating mixture containing lindane 14%, thiram 56%, and inert 30%, manufactured by E. I. du Pont de Nemours and Co.

treated with fungicide were no more susceptible to decay than those treated with thiram. There were no significant differences indicated by the type of insecticide used or by dosage or method of seed treating.

Zucchini Squash.—The inclusion of the fungicide thiram in the treatments reduced the percentage of seeds destroyed by decay organisms. Results of all treatments with thiram except one were significantly better than those of the check. Dieldrin at ⅔ and 1½ ounces significantly reduced plant emergence below that of the check. Although emergence after the use of lindane alone was slightly below that of the check, the differences were not significant.

Cucumber.—The results in this test were similar to those recorded for zucchini squash. Effects of treatments that included the fungicide were similar and significantly better than those of the check. Averages for the various treatments indicate that dieldrin, both as slurry and as dust, tended to be more ef-

fective than lindane.

Watermelon.—Because of cool, rainy weather often encountered at planting time, the emergence of the watermelon plants was not so high as might be desired. Seed-corn maggots were present in the plot, however, and plant emergence in the untreated rows was very low (13 per cent). Emergence after use of the fungicide alone (22.8 per cent) was considerably less than that resulting from most of the insecticide-plus-fungicide combinations.

Comparison of results of the two methods of treatment shows that the slurries were slightly better than the dry treatments. Results with lindane and dieldrin, plus thiram, were better at the 1½-ounce dosages than at lighter dosages. The insecticides used without the fungicide reduced plant stands below those of the check, with one exception. Treatment with 1½ ounces of dieldrin resulted in the lowest plant emergence.

Muskmelon.—This was another experiment adversely affected by weather conditions. The average plant emergence after the treatments including the fungicide ranged from 52.0 per cent to 66.1 per cent, while that of the check was 34.8 per cent. Results of dieldrin-thiram-slurry treatments were significantly better than those of the check.

Crookneck Squash.—Seedling emergence of crookneck squash was less than expected because of the necessity of deep planting in loose, trashy soil. Seed-corn maggots were very abundant, however, and these combined with decay organisms reduced the emergence on untreated rows to 6.0 per cent, as shown in table 1. The fungicide alone increased emergence to 21.2 per cent, and the insecticide-plus-fungicide combinations increased emer-

Table 2.—Percentage emergence of cotton plants after seed treatments with various dosages of lindane with and without *Ceresan M.* Riverside, California, 1953.[1]

Material[2]	Dosage in Ounces	Acid-Delinted Seed	Machine-Delinted Sfed
	Dust-Treated		
Lindane +*Ceresan M*	⅓ 1½	70.2	78.4
Lindane +*Ceresan M*	⅔ 3	76.6	84.0
Lindane +*Ceresan M*	1½ 3	71.6	82.0
Ceresan M	3	67.8	80.2
	Slurry-Treated		
Lindane +*Ceresan M*	⅓ 1½	72.2	84.8
Lindane +*Ceresan M*	⅔ 3	77.0	77.8
Lindane +*Ceresan M*	1½ 3	76.0	79.8
Lindane +Inert	⅔ 3	60.0	83.6
Lindane +Inert	1½ 3	69.6	75.2
Ceresan M	3	72.6	—
Untreated		64.4	69.4
Mean		70.7	79.5
L.S.D. at 5% level		n.s.	n.s.
Student's paired plots		1:1999	

[1] Each treatment consisted of 100 seeds replicated 5 times.
[2] Lindane was used at 75%. The active ingredient in *Ceresan M* is ethyl mercury *p*-toluene sulfonanalide, 7.7%. The inert material was pyrophyllite.

Table 3.—Percentage emergence of spinach, onion, and green pea plants after dust seed treatments with various dosages of lindane and dieldrin with and without thiram, Riverside, California, 1953.

Material[1]	Dosage in Ounces	Spinach[2] Orange County	Spinach[2] Riverside	Onion[3]	Green Pea[3]
Lindane +thiram	¼ 3	53.4	29.7	44.0	86.2
Lindane +thiram	½ 3	45.0	35.0	42.0	85.6
Lindane +thiram	1½ 3	54.4	26.6	24.8	83.8
Dieldrin +thiram	¼ 3	45.2	30.7	45.6	80.8
Dieldrin +thiram	½ 3	48.2	38.3	47.4	81.2
Dieldrin +thiram	1½ 3	47.5	47.5	49.8	75.2
Lindane +Inert	¼ 3	44.4	23.7	40.2	76.0
Lindane +Inert	½ 3	43.4	37.6	43.6	79.6
Lindane +Inert	1½ 3	42.7	37.1	42.6	66.2
Dieldrin +Inert	¼ 3	48.3	34.6	33.0	65.6
Dieldrin +Inert	½ 3	48.7	47.4	37.4	72.2
Dieldrin +Inert	1½ 3	47.2	44.0	60.8	68.2
Thiram	3	41.3	38.6	32.8	77.2
Untreated		36.8	39.0	45.4	80.8
L.S.D. at 5% level		8.76	n.s.	n.s.	n.s.

[1] All materials were 75% concentration; the inert material was pyrophyllite.
[2] Each treatment consisted of 2.1 grams or an average of 206 seeds replicated 5 times.
[3] Each treatment consisted of 100 seeds replicated 5 times.

gence to as high as 49.4 per cent. Dieldrin at ⅔ ounce plus thiram at 4 ounces was significantly the best treatment (49.4 per cent).

Banana Pink Squash.—Seed-decay organisms were the principal cause of emergence differences in this test. Emergence was similar in treatments using fungicide alone or in combination with the insecticide. There was no significant difference in the comparison of results of the three dosages used for seed treatment, either with or without fungicide.

Royal Acorn and Early White Bush Squash.—No significant differences were found. Seed-corn maggots were not present, and seed-decay organisms caused little damage. Lindane used alone did not reduce emergence significantly below that of the check plot.

Percentages of plant emergence at the various dosages for each treatment were averaged, and the means of these averages are shown in the last column of table 1. For this group of cucurbits it is evident that results of treatments including thiram were better than those of the check. The insecticides used alone had a slight phytotoxic effect, and dry treatments were not as effective as slurries.

Cotton.—Acala 4-42 cotton seed was treated with three dosages of lindane and two dosages of a fungicide, *Ceresan M*, to determine the possible phytotoxic effects upon seed germination. Both acid-delinted and machine-delinted seeds were tested. The materials were used both as dry and as slurry treatments. The data presented in table 2 were analyzed by analysis of variance and by Student's Paired Plots method (Hayes & Garber 1927). No significance at the 5 per cent level was found, but in comparing the germination figures of the machine- and acid-delinted seeds it was found that the probability of machine-delinted cotton giving a higher percentage of germination was 1:1999.

Spinach, Onion, and Green Peas.—Spinach-seed experiments in Orange County were arranged in soil abundantly infested by the seed-corn maggot. The maggots were controlled in the region of the seed but subsequent inspection revealed maggots working in the seedling stems, causing plant mortality. Insecticide-fungicide combinations were better than the untreated, and lindane tended to be better than dieldrin, although differences were not significant.

There were no significant differences when the data from the spinach, onion, and pea plots at the Experiment Station were analyzed statistically, and it may be concluded that the seed treatments did not materially affect germination.

SUMMARY.—Lindane and dieldrin were used with either a fungicide or an inert carrier to treat seeds of green pea, spinach, onion, cotton, and nine varieties of cucurbits. For treatment of cucurbit seeds the insecticides were used as slurries and as dusts at ⅓, ⅔, and 1½ ounces, and the fungicide (thiram) was used at 1½ and 3 ounces, per 100 pounds of seed. Emergence counts indicated that a fungicide and an insecticide must be combined to control both the seed-corn maggots, *Hylemya cilicrura* (Rond.), and seed-decay organisms. Lindane and dieldrin were equally effective in controlling seed-corn maggots at the three dosages tested. When the insecticides were used without a fungicide, the seed was more predisposed to injury by decay organisms, and, provided that maggots were not present, plant emergence was often less than in untreated plots.

Machine-delinted and acid-delinted cotton seeds were treated with lindane (75 per cent) at ⅓, ⅔, and 1½ ounces, and with either *Ceresan M* or an inert carrier at 1½ and 3 ounces per 100 pounds of seed. Both slurry and dry seed-treating methods were used. No significant differences in results of treatments were found. Germination of the machine-delinted cotton seed was better than that of the acid-delinted seed.

Seeds of green pea, onion, and spinach were treated with lindane or dieldrin at ¼, ½, and 1½ ounces plus thiram or an inert carrier at 3 ounces per 100 pounds of seed. Only dry treatments were made. Plant emergence of spinach, peas, and onions was not adversely affected by seed treatments. Lindane and thiram combinations gave better seed protection than other treatments.

LITERATURE CITED

Brooks, J. W., and L. D. Anderson. 1947. Toxicity tests of some new insecticides. JOUR. ECON. ENT. 40(2): 220–8.

Elmore, J. C. 1953. Treatment of bean seed for the control of the seed-corn maggot. JOUR. ECON. ENT 46(6): 1054–9.
Hayes, H. K., and R. J. Garber. 1927. Breeding crop plants. 2d ed. McGraw-Hill Book Co., Inc. (Pp. 86–94).
Howe, W. L., W. T. Schroeder, and K. G. Swenson. 1952. Seed treatment for control of seed-corn maggot and seed-decay organisms. New York State Agr. Expt. Sta. Bul. 752.
Lange, W. H., Jr., E. C. Carlson, and W. R. Corrin. 1951. Seed treatments for control of the seed-corn maggot in northern California. JOUR. ECON. ENT. 44(2): 202–8.
Reid, W. J., Jr. 1936. Relation of fertilizers to seed-corn maggot injury to spinach seedlings. JOUR. ECON. ENT. 29(5): 973–80.
Reid, W. J. 1940. Biology of the seed-corn maggot in the coastal plain of the South Atlantic states. U. S. Dept. Agr. B.E.P.Q. Tech. Bul. 723.
Ristich, S. S., and H. H. Schwardt. 1949. Biology and control of the seed-corn maggot on beans in New York. JOUR. ECON. ENT. 42(1): 77–80.
Turner, Neely. 1945. Seed treatments to control seed-corn maggots. Conn. Expt. Sta. Bul. 501 (45th Report): 95–6.

The Behavior of Systox-isomers in Bean and Citrus Plants[1]

R. L. METCALF, R. B. MARCH, T. R. FUKUTO, and MARION MAXON, *University of California Citrus Experiment Station Riverside*

Radiotracer molecules are ideally suited for studying the behavior of systemic insecticides in plants, and this technic has been used extensively with schradan (David 1951, Hartley & Heath 1951, Heath *et al.* 1952, Metcalf & March 1952). Preliminary investigations of the biochemistry of radioactive Systox[2] have been reported by Heath (1952),[3] and certain aspects of its penetration, translocation, and excretion in plants have been disclosed by Tietz (1954). In this study the insecticidal behavior of P^{32}-labeled Systox-isomers, 0,0-diethyl 0-ethyl-beta-mercaptoethyl thionophosphate, (hereafter designated as the thiono-isomer); and 0,0-diethyl S-ethyl-beta-mercaptoethyl thiophosphate, (hereafter designated as the thiol-isomer), have been compared in lemon and bean plants, and information has been developed on their quantitative metabolism.

MATERIALS AND METHODS.—*Tracer Preparations.*—The several radioactive preparations used in these experiments are described below. The syntheses of P^{32}-labeled Systox-isomers have been reported by Fukuto & Metcalf (1954).

A. A sample[4] lableled with S^{35} and composed of 43.4 per cent thiono- and 56.6 per cent thiol-isomer. This material had an initial relative activity of 4.5 c.p.s./γ.

B. A sample[5] labeled with P^{32} and composed of approximately 99.9 per cent thiono-isomer. This material had an initial relative activity of 0.88 c.p.s./γ.

C. A sample prepared in our laboratories with P^{32} and composed of approximately 99 per cent thiono-isomer. This material had an initial relative activity of 2.42 c.p.s./γ, and a portion was converted to an 86 per cent thio-isomer with the same activity.

D. A sample prepared in our laboratories with P^{32} and composed of approximately 99 per cent thiono-isomer. This material had an initial relative activity of 2.08 c.p.s./γ, and a portion was converted to a 70 per cent thiol-isomer of the same activity.

Methods of Assay.—The methods of assay were similar to those previously described (Metcalf & March 1952). Weighed portions of leaves or other plant tissues were homogenized in water in a ratio of 1:10 parts by weight, and aliquots of the suspension were removed for radiological assay. In the experiments reported in tables 1, 2, and 3, the aliquots were placed in stainless-steel cupped planchets and wet-ashed with HNO_3 at 300° C. in a muffle furnace prior to counting. This procedure was very satisfactory for the assay of schradan, but upon careful investigation it was found that with

[1] This work was supported in part by grants from the U. S. Atomic Energy Commission, Contract AT(11-1)34 Project 6, Dr. F. M. Turrell, Director; and the Chemagro Corp. Paper No. 882.
[2] Trade-mark Chemagro Corp., New York.
[3] Heath, D. F. 1952. Paper presented to International Congress of Crop Protection, Paris.
[4] Furnished through the courtesy of Prof. R. M. Chatters, Dept. Botany, Oklahoma A & M College.
[5] Furnished through the courtesy of Dr. Gerhard Schrader, Farbenfabriken Bayer, Leverkusen, Germany.

Table 1.—Distribution of thiono-isomer and metabolites in leaves of lemon seedlings growing in water culture containing 0.0059% thiono-isomer and toxicity of leaves.[1]

Period Preceding Assay	Position of Leaves	Radioactive Compounds γ/g. of Leaf	48-Hour Per Cent Mortality		ChE Inhibition 10 Mg. Leaf
			Mites[2]	Thrips[3]	
24 hours	Basal	13	25	0	18%
	Median	13	35	5	11
	Terminal	30.5	90	0	0
3 days	Basal	31	45	10	19
	Median	44	15	15	16
	Terminal	39	35	15	8
7 days	Basal	41	80	0	18
	Median	35	20	0	10
	Terminal	235	50	0	4
14 days	Basal	82	70	5	23
	Median	124	60	80	32
	Terminal	80	45	0	5
21 days	Basal	24	65	5	82
	Median	48	70	5	48
	Terminal	79	90	30	14
28 days	Basal	126	95	35	37
	Median	210	80	100	48
	Terminal	91	70	0	0

[1] Assay values average of 2 leaves each.
[2] Citrus red mite, *Metatetranychus citri* (McG.).
[3] Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché).

the more volatile Systox, a considerable loss in activity occurred during the oxidative destruction. In six series of tests involving various amounts of plant tissue and from 1 to 250γ of Systox, a relatively consistent loss of activity, averaging 26 per cent, occurred during the ashing process. Therefore, it is estimated that the values in tables 1, 2, and 3 represent only about 75 per cent of the total activity present. The ashing practice was discontinued, and the remainder of the data were obtained by evaporating the planchets to dryness in a slight current of air. This procedure was found to give nearly complete recoveries of known amounts of thiono- and the thiol-isomers, when used with the relatively high energy P^{32}-tracers ($\beta = 1.712$ MEV) where no correction for self-absorption is necessary until thicknesses of 50 mg./cm.^{2} are encountered (Kamen 1947). With S^{35}, however, the energy is much weaker ($\beta = 0.166$ MEV), and corrections for self-absorption are necessary. The usefulness, therefore, of the S^{35}-labeled product was more limited.

Table 2.—Distribution of thiono-isomer and metabolites in leaves of lemon seedlings treated topically at base of trunk with 20 μl. of thiono-isomer and toxicity of leaves.[1]

Period Preceding Assay	Position of Leaves	Radioactive Compounds γ/g. of Leaf	48-Hour Per Cent Mortality		ChE Inhibition 10 Mg. Leaf
			Mites[2]	Thrips[3]	
24 hours	Basal	0	25	0	0%
	Median	8	20	0	0
	Terminal	8	5	0	7
3 days	Basal	10	20	10	12
	Median	93	35	10	2
	Terminal	38	25	10	6
7 days	Basal	30	50	5	10
	Median	150	55	0	0
	Terminal	182	65	20	15
14 days	Basal	10	5	0	3
	Median	232	20	45	0
	Terminal	284	90	75	73
21 days	Basal	19	10	0	19
	Median	181	80	20	0
	Terminal	226	90	80	36
28 days	Basal	16	15	0	10
	Median	359	30	0	0
	Terminal	337	75	25	14

[1] Assay values average of 2 leaves each.
[2] Citrus red mite.
[3] Greenhouse thrips.

After preparation, the planchets were counted with a standard Geiger-Müller end window tube and were corrected for background and progressive decay to give values expressed in terms of γ of thiono- or thiol-isomer. Samples showing less than 0.03 c.p.s. greater than background were considered as possessing no activity, inasmuch as this value represents the standard error of the average background.

The technics for plant growth in water culture and for determination of the contact toxicity of leaves to the two-spotted spider mite, *Tetranychus bimaculatus* Harvey; the citrus red mite, *Metatetranychus citri* (McG.); and the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), have been previously described (Metcalf & Carlson 1950).

Anticholinesterase activities of the

Table 3.—Penetration of thiono-isomer into lemon leaves dipped in 0.1 per cent solution containing 0.01 per cent wetting agent.

Hours After Treatment	Radioactive Compounds γ/g.		
	On Leaf Surface	In Leaf Homogenate	Per Cent Penetrated
1	398	21.8	5.0
6	290	71.0	19.6
12	302	92.5	23.4
24	481	83.0	14.7
48	421	161	27.7
72	120	210	66.7
96	119	338	74.1
120	106	225	67.8

breis were measured manometrically using 0.1 ml. of leaf homogenate, acetylcholine bromide 0.01M, and house fly-head cholinesterase (Metcalf & March 1952).

Paper Chromatography of Systox Isomers and Metabolites.—Two systems of reversed phase paper chromatography have been found which provide useful separations of thiono- and thiol-isomers and the compounds produced from them in plant tissues. The system of Metcalf & March (1953) for chromatography of parathion and related thionophosphates works very well with Systox, and this application has been described in detail (March *et al.* 1954). This system, method (A), employs Whatman No. 1 paper uniformly impregnated with Dow Corning Corporation silicone 550 from a 5 per cent petroleum ether (*Skellysolve B*) solution and as solvent, the upper phase of a mixture by volume of 10 pts. chloroform, 10 pts. absolute ethanol, and 6 pts. water. Gage (1953) proposed a different system, method (B), for the separation of parathion and metabolites. We have modified Gage's system in minor detail and applied it to Systox using Whatman No. 1 paper impregnated with 50 per cent propylene glycol in ethanol, and dried in air. The solvent is a mixture by volume of 8 pts. petroleum ether (*Skellysolve B*) and 2 pts. benzene, saturated with propylene glycol. The average R_f values of the thiono- and thiol-isomers and their metabolites are given below. The procedure for the quantitative evaluation of the radioactive components on the paper has been described elsewhere (Fukuto & Metcalf 1954). Examples of the activity-R_f curves obtained are given in figures 3 and 4.

	R_f VALUES	
	Method A	Method B
Thiono-isomer	0.05±0.01	0.99±0.01
Principal plant metabolite of thiono-isomer	0.89±0.08	0.01−0.03
Thiol-isomer	0.69±0.04	0.80±0.02
Principal plant metabolite of thiol-isomer	0.95±0.02	0.01−0.03

Plant material was prepared for paper chromatography by homogenizing in an all-glass Potter-Elvehjem homogenizer using 1 ml. of water to each 0.1 g of. plant tissue. After homogenization, the material was centrifuged and the water solution extracted with an equal volume of chloroform. The chloroform layer was separated and evaporated by a stream of air at room temperature. After removal of the chloroform, the dried residue was taken up in about 50 μl. of acetone, and this solution was applied to the paper.

DISCUSSION OF RESULTS.—*Penetration and Translocation of Systox Applied to Lemon Roots in Water Culture.*—The uptake and distribution of P^{32} thiono-isomer (Sample B) was studied by adding this material dissolved in three parts of a polyethylene-glycol ether dispersing agent[6] to water-culture solutions containing lemon seedlings, so that the final colloidal suspension contained 0.0059 per cent w/v thiono-isomer. At the intervals indicated in table 1, two leaves were removed from each of three areas (basal, median, and terminal) of the stem of a single seedling. Equal sized pieces from the tips of the two leaves, (totalling 0.2 g.) were cut off, combined, homogenized, and assayed for total radioactivity and anticholinesterase activity. The remainders of the leaves were placed in Munger cells, and each was infested with 20 adult female citrus red mites, or adult female greenhouse thrips. The data in table 1 indicate a progressive increase in the amount of radioactivity present in the leaves with time. The radioactive products were translocated most strongly to the median and terminal leaves, and the total distribution in the six plants in this experiment was as follows:

LEAF POSITION	RADIOACTIVE METABOLITES	
	γ/g.	Per cent
Basal	317	23.5
Median	474	35.2
Terminal	554	41.3

These results are not greatly different from those previously obtained with schradan either in rate of uptake from a solution of equal concentration, or in dis-

[6] *Thiosolve.*

tribution, although the radioactivity concentrated somewhat more in the terminal leaves. The anticholinesterase activity was higher, however, in the basal and median leaves, perhaps indicating greater metabolic activity there or a greater loss of the metabolites in the terminal leaves, and in general the toxicity to the test organisms seemed to be better correlated with anticholinesterase activity than with total radioactivity.

At the conclusion of the water culture experiments, 60 days after treatment, the total radioactivities in the various portions of the lemon seedlings in γ/g. were:

	PLANT 1	PLANT 2
Root	4950	3840
Stem	2188	1570
Leaf	2120	2260

Penetration and Translocation of Systox Applied to Bark.—Essentially the same type of experiment was repeated using the same sample (B) of thiono-isomer but applying 20 μl. to the bark of two large lemon seedlings about 5 cm. above the soil level. At each of the intervals indicated in table 2, one basal, one terminal, and one median leaf were removed from each plant and assayed for radioactivity, anticholinesterase activity, and toxicity to mites and thrips as described above. Although the total amount of thiono-isomer available per plant was only one-fifth that of the water culture experiments, the bark-treated plants accumulated total radioactivity in the leaves at a somewhat higher rate. The summation of data indicates a pronounced distribution in favor of the median and terminal leaves.

LEAF POSITION	RADIOACTIVE METABOLITES	
	γ/g.	Per cent
Basal	85	3.9
Median	1023	46.8
Terminal	1075	49.3

The anticholinesterase measurements agree fairly well with the toxicity to thrips and mites but do not correlate with the total amount of radioactivity present. In comparison with previously published data on schradan (Metcalf & March 1952), the maximum concentrations of thiono-isomer or metabolites in the lemon leaves were only about one-fifth those obtained with schradan applied in equal concentrations under similar conditions. When, however, the topical applications were made with the thiol-isomer, the absorption and translocation was much more rapid (Table 4), and the total concentration of radioactivity in the leaves was of the same magnitude as that obtained with schradan.

Penetration into Lemon Leaves.—When lemon leaves were dipped into a suspension of 0.1 per cent thiono-isomer (Sample B) and the radioactivity on the surface and in the tissues was measured as previously described for schradan (Metcalf & March 1952), the results in table 3 were secured. These indicate a fairly rapid penetration, so that after 3 days more than half the total dosage was found in the interior of the leaf. The rate

Table 4.—Rates of translocation and metabolism of thiono- and thiol-isomers in lemon seedlings treated topically at the base of trunk with 20 μl. of compound.

PERIOD PRECEDING ASSAY	RADIOACTIVE COMPOUNDS γ/g. OF LEAF[1]	PER CENT AS		METABOLITE	24-HOUR PER CENT MORTALITY		ChE INHIBITION 10 MG. LEAF
		Thiono-Isomer	Thiol-Isomer		Mites[2]	Thrips[3]	
24 hours	Thiono-isomer 0					0	0
	Thiol-isomer 67	24	5.5	70.5	100	100	67
2 days	Thiono-isomer 88	29	0.0	71	25	70	10
	Thiol-isomer 708	4.5	5.0	90.5	—	—	96
4 days	Thiono-isomer 304	3	0	97	85	100	28
	Thiol-isomer 1740	0	0	100	—	—	100
8 days	Thiono-isomer 382	3.5	0	96.5	—	—	34
	Thiol-isomer 1680	22	14	64	—	—	100

[1] Calculated for M. W. 258.
[2] Citrus red mite.
[3] Greenhouse Thrips.

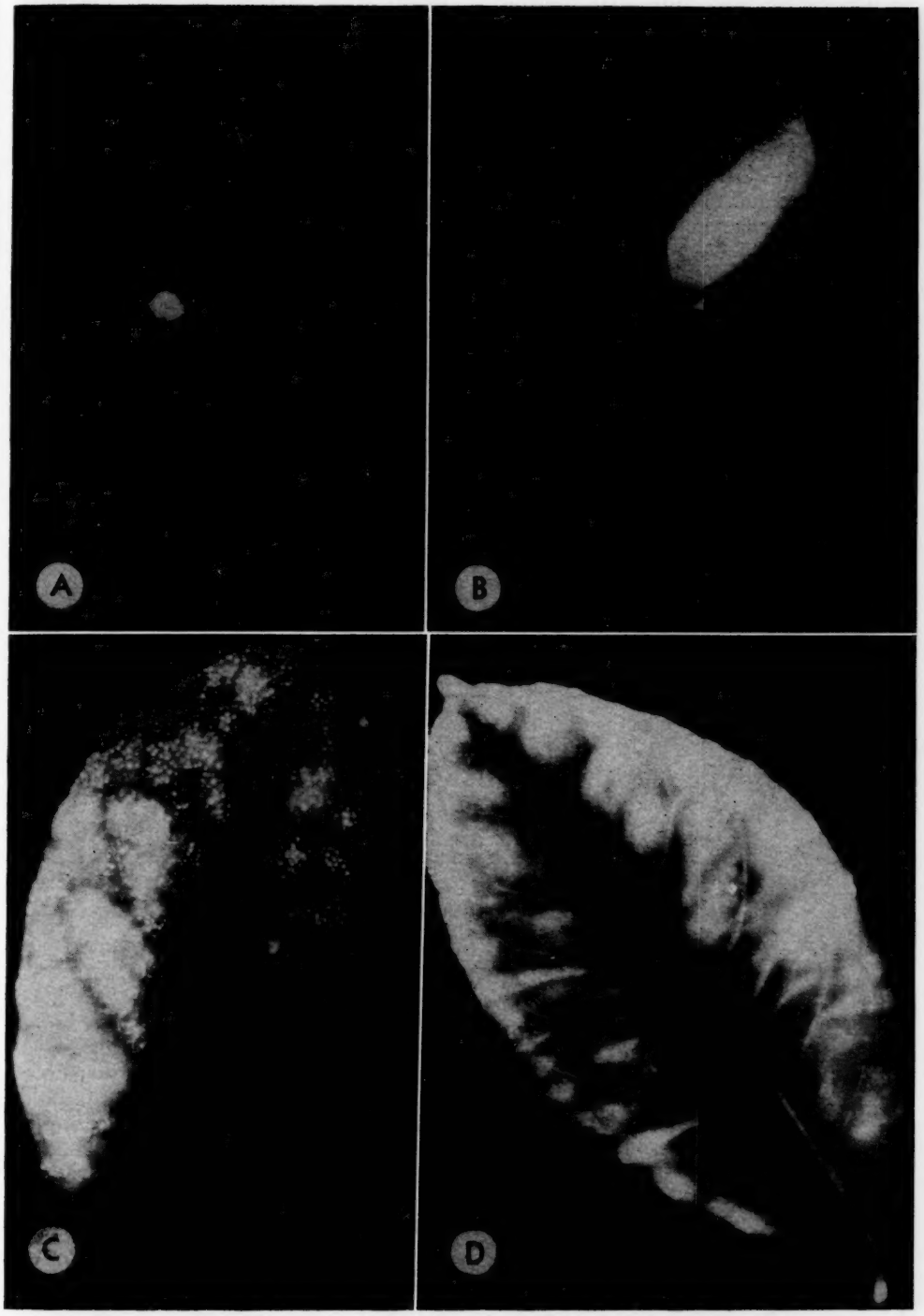


FIG. 1.—Radioautographs of lemon leaves showing comparative behavior of P^{32}-labeled Systox-isomers. (A) 11 days after topical treatment at leaf center with 1 μl. thiono-isomer; (B) 11 days after topical treatment at leaf center with 1 μl. thiol-isomer; (C) 7 days after topical treatment of base of seedling with 20 μl. thiono-isomer; and (D) 4 days after topical treatment at base of seedling with 20 μl. of thiol-isomer.

of penetration was only slightly slower than that of schradan under identical conditions.

When the penetration and dispersion of nearly pure thiono-isomer (Sample C) and thiol-isomer (Sample C) were compared by placing 1 μl. of each on the approximate center of the upper surface of each of several lemon leaves and determining the dispersion by radioautography at the end of 11 days (Figure 1), it was found that the thiol-isomer was present throughout almost the entire leaf interior while the thiono-isomer was found only in a small area near the site of application. This information, together with that in table 4 and in figures 3 and 4, clearly shows that the thiono-isomer penetrates plant tissues much less rapidly than the thiol-isomer.

Absorption and Metabolism of Systox Isomers in Bean and Lemon Plants.—Topical application of 10 μl. of P^{32}-labeled thiono- and thiol-isomers (Sample C) to the stem of Black Valentine bean plants resulted in the rapid absorption and translocation of radioactive compounds into the leaves. The results of several experiments of this nature are plotted in figure 2 from which it appears that the accumulation of total radioactivity in the primary leaves is a linear function of time. The thiol-isomer accumulates about 6.3 times as fast as the thiono-isomer, as measured by the comparative slopes of the two lines. Apparently the areas treated were nearly at the saturation point since values obtained by the application of 20 and 40 μl. were of approximately the same magnitude.

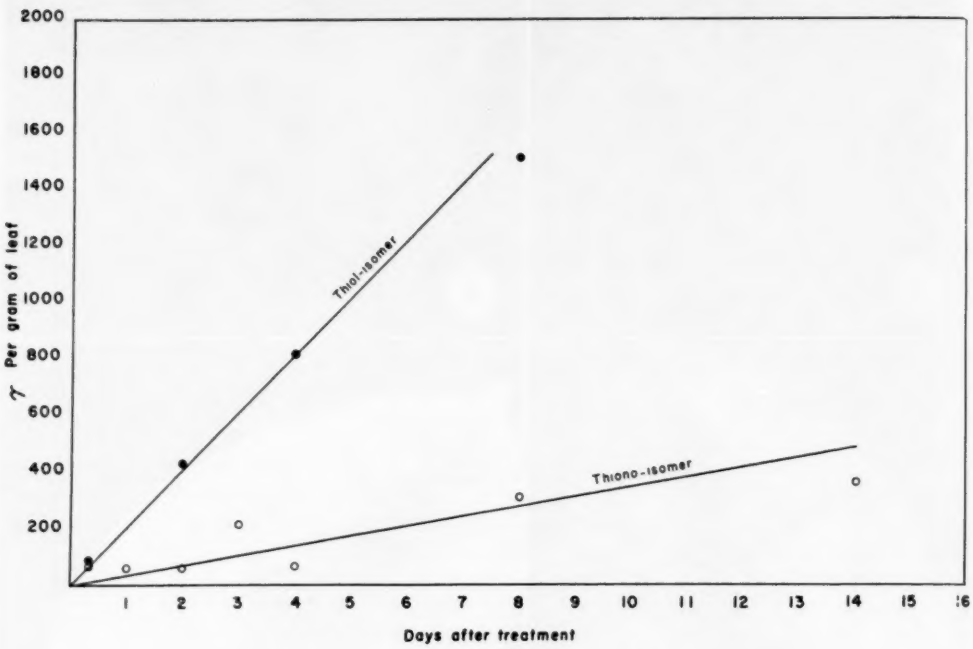


FIG. 2.—Accumulation of total radioactivity in primary leaves of bean plants topically treated on stem with thiono- and thiol-isomers of Systox.

Ten μl. of thiono- and thiol-isomers (Sample C) were applied topically to the stems of bean plants, and at various intervals the amount and nature of the radioactive products in the leaves were studied by extracting them in chloroform, concentrating, and separating the extractives by means of the two systems of reversed phase paper chromatography previously described. Following the experiences of Heath (1952)[3] chloroform was selected as the most suitable extraction solvent for all the compounds likely to be present. Experiments with benzene, *iso*-octane, and acetonitrile showed that these solvents were not as suitable as chloroform

for extracting the Systox-isomers, and their metabolites. The results of typical sets of experiments are presented in figures 3 and 4. These were repeated several times with almost identical results. In these activity-R_f plots of the profiles of the paper chromatograms, the relative percentages of each constitutent present are indicated. The relative activities in c.p.s., which are indicative of the relative amounts of material present in the leaves at the indicated times, are not comparable between figures 3 and 4 inasmuch as these experiments were carried out 80 days apart and the amounts of radioactivity shown were not corrected for decay.

Comparisons of paper chromatograms from chloroform extracts, water extracts and expressed leaf juices of thiono- and thiol-isomer-treated bean plants showed no significant differences in the distribution and relative amounts of the various labeled compounds present.

From these figures it is apparent that the thiol-isomer is absorbed much more rapidly than the thiono-isomer as the concentration of radioactivity in the thiol-isomer plant in 2 hours was roughly

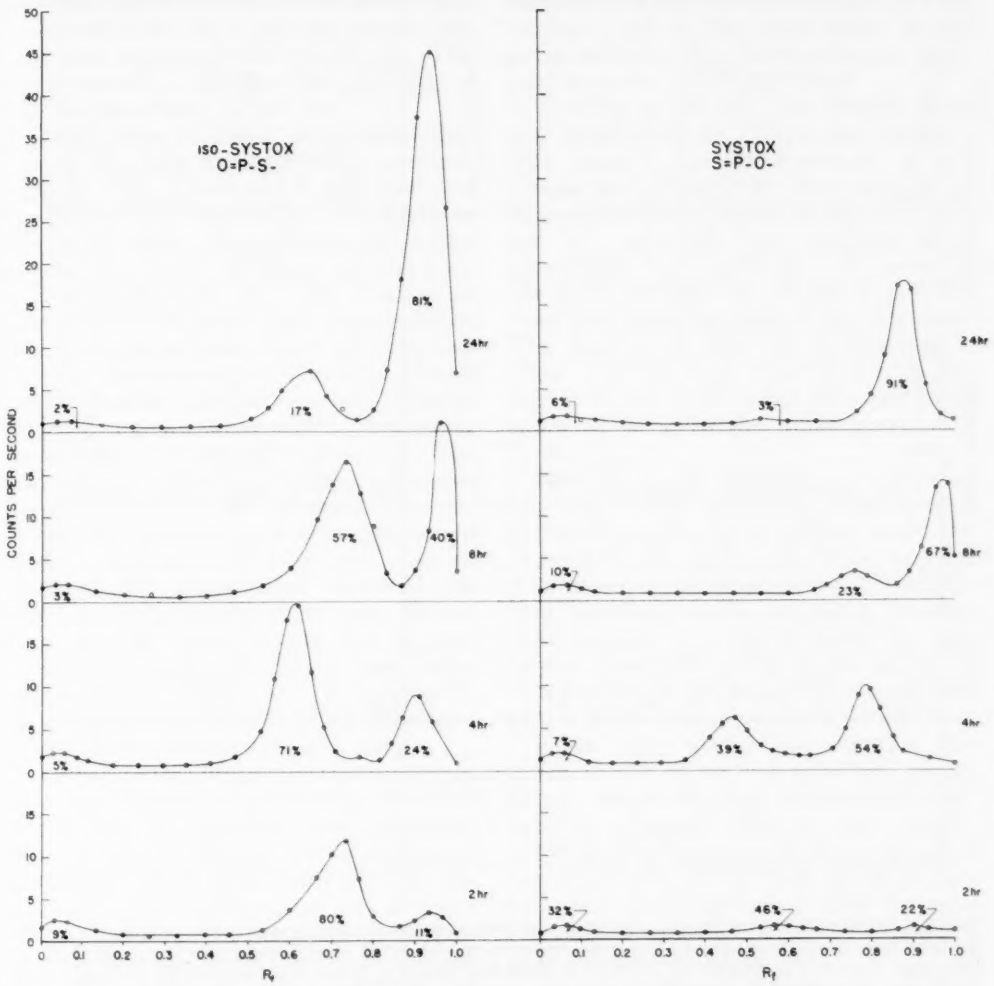


FIG. 3.—Activity-R_f curves from silicone-treated paper chromatograms of the radioactive constituents of bean leaves at intervals after topical treatment with 10 μl. of Systox-isomers from sample C. In this graph, 1 c.p.s. is equivalent to about 0.7 γ. (Iso-systox = thiol-isomer and systox = thiono-isomer.)

equal to that of the thiono-isomer plant in 24 hours. At this time 80 to 90 per cent of both the isomers had been metabolized, and this amount increased until after 2 and 3 days 95 to 99 per cent of the P^{32} in the leaves was in the metabolized forms.

Experiments of this type were repeated with lemon seedlings treated with 20 μl. of 97 to 100 per cent of the radioactivity in the leaves from both precursors became metabolized in the plant in 4 days. The ChE inhibition from leaf extracts and the toxicity of the leaves to mites and thrips increased over this interval roughly proportionately to the uptake of the P^{32}.

Unmetabolized thiono-isomer accumu-

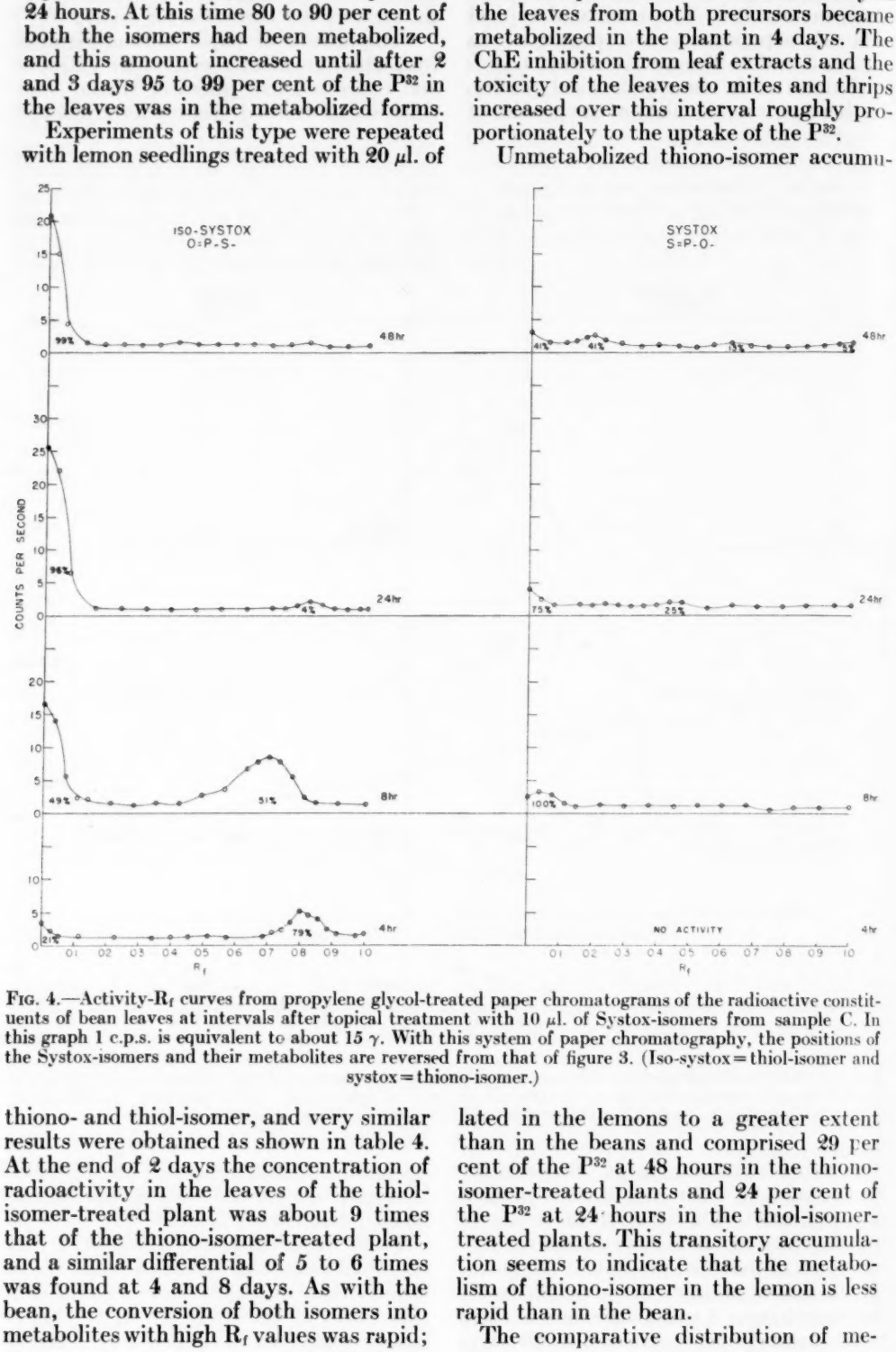


FIG. 4.—Activity-R_f curves from propylene glycol-treated paper chromatograms of the radioactive constituents of bean leaves at intervals after topical treatment with 10 μl. of Systox-isomers from sample C. In this graph 1 c.p.s. is equivalent to about 15 γ. With this system of paper chromatography, the positions of the Systox-isomers and their metabolites are reversed from that of figure 3. (Iso-systox = thiol-isomer and systox = thiono-isomer.)

thiono- and thiol-isomer, and very similar results were obtained as shown in table 4. At the end of 2 days the concentration of radioactivity in the leaves of the thiol-isomer-treated plant was about 9 times that of the thiono-isomer-treated plant, and a similar differential of 5 to 6 times was found at 4 and 8 days. As with the bean, the conversion of both isomers into metabolites with high R_f values was rapid; lated in the lemons to a greater extent than in the beans and comprised 29 per cent of the P^{32} at 48 hours in the thiono-isomer-treated plants and 24 per cent of the P^{32} at 24 hours in the thiol-isomer-treated plants. This transitory accumulation seems to indicate that the metabolism of thiono-isomer in the lemon is less rapid than in the bean.

The comparative distribution of me-

tabolites of the thiono- and thiol-isomers in lemons following application to the base of the plant stem is quite different as revealed by the radioautographs, figures 1C and D. These show that the thiono-isomer-metabolite is sharply localized in the oil glands of the leaf while the thiol-isomer-metabolite is much more generally distributed throughout the rapidly growing peripheral leaf tissues. This is evidence of the greater lipid solubility of the thiono-isomer metabolite.

From these studies it is apparent that the thiol-isomer is considerably more soluble in plant juices and is absorbed and translocated at rates of 5 to 10 times those of thiono-isomer. Very little thiono-isomer is translocated in the plant, but the compound is converted (apparently nearly as fast as it is absorbed) into a more soluble, less stable metabolite, which is responsible for the systemic action. The thiol-isomer, on the contrary, is quite rapidly metabolized to a more water soluble, less stable form which is the active systemic. The rate of conversion of both thiono- and the thiol-isomers into the metabolites is very rapid, and in 24 hours in bean plants and 4 days in lemon plants 95 per cent or more of the translocated material has been metabolized. There is some indication that the thiono-isomer may in part be isomerized into the thiol-isomer before translocation occurs, and it is possible that this occurs either on the treated surface or in the underlying plant tissues.

The evidence obtained in this investigation corroborates in general that of Heath (1952)[3] for the behavior of the thiol-isomer in plants. From the quantitative aspects of metabolism, however, the evidence from two independent sets of paper chromatographic studies, conducted with entirely different mobile solvents and impregnated stationary phases, appears to show that a single toxic metabolite comprises 90 per cent or more of the initial metabolic products of the thiol-isomer. It seems possible that Heath's metabolite D_3 may be the thiono-isomer metabolite formed from small amounts of thiono-isomer present in the thiol-isomer preparation.

Heath believes that the thiono-isomer contributed little or nothing to the systemic behavior of the technical product. The results obtained here show that the thiono-isomer is metabolized into a material which is an effective systemic insecticide. The slow penetration and metabolism of the thiono-isomer is of definite importance in producing a long term systemic action as well as in providing considerable contact toxicity. Additionally there is the possibility of the slow isomerization of the thiono-isomer to the thiol-isomer by the action of heat, ultraviolet radiation, or by enzyme action within the plant.

Toxicity of Thiono- and Thiol-Isomers and Metabolites to Thrips and Mites.—The relative contact toxicities of the two isomers (Sample D) were assessed by dipping mature Valencia oranges in standard w/v solutions and exposing adult greenhouse thrips and citrus red mites to the dried residues for 24 hours, and the results as shown in table 5 were obtained. The data show that the thiol-isomer is about five times as toxic as the thiono-isomer to the adult citrus mite and three times as toxic to the adult greenhouse thrips.

Because of the difficulty in obtaining any appreciable quantities of the Systox-metabolites, this direct method could not be used for the estimation of their toxicity. The relative toxicities of these metabolites, however, can be estimated from the data in tables 1, 2, and 4, where the mortalities produced among thrips and mites as a result of feeding on known quantities of the metabolites, have been determined.

These data would indicate that the LD_{100} to the citrus red mite and greenhouse thrips for the thiono-isomer-metabolite is about 300γ/g. leaf weight, while for the thiol-isomer-metabolite, it is less than 40γ per g. leaf weight. This ratio is in good agreement with the relative effectiveness of the two metabolites as cholinesterase inhibitors.

Anticholinesterase Activity of Thiono- and Thiol-Isomer-Metabolites.—To determine something of the activities of the compounds separated on the paper chromatograms, a series of chromatograms (method A) were prepared from the chloroform extractives of bean leaves 4 to 24 hours after topical treatment of the stems with 10 μl. of thiono- and thiol-isomers (Sample C). The spots where P^{32}-containing compounds were found were cut out in equal sized areas, diced and the pieces placed in Warburg flasks along with the

Table 5.—Relative contact toxicity of thiono- and thiol-isomers to *Metatetranychus citri* and *Heliothrips haemorrhoidalis*.

	24-HOUR PER CENT MORTALITY			
	Thiono-Isomer		Thiol-Isomer	
% CONC.	*M. citri*	*H. haemorrhoidalis*	*M. citri*	*H. haemorrhoidalis*
0.05	100	100	100	100
0.03	100	100	96	100
0.01	100	82	96	100
0.008	93	78	96	100
0.005	56	88	97	100
0.0025	9	28	98	96
0.001			70	16
0.0008			34	4

ingredients for fly-brain ChE assay. The results from typical assays are given in table 6. These results indicate that pure thiono-isomer is nearly inactive as a ChE inhibitor but that the thiol-isomer at the same concentration is quite effective while the metabolites of both thiono- and thiol-isomers are highly inhibitory.

Vapor Effects of Thiono- and Thiol-Isomers.—The thiono- and thiol-isomers are quite volatile esters with almost identical vapor pressures, extrapolated from Schrader's (1952) data as about 1.4×10^{-3} mm. Hg/20° C. although Ripper (1952)[7] gives a figure of 5×10^{-4} mm. Hg/20° C. This vapor pressure is high enough to cause a pronounced loss in the activity of P^{32}-thiono-isomer-standards exposed as dilute films. A number of investigators have commented on the possibility of vapor toxicity. It was of interest, therefore, to measure the possible expiration of thiono- and the thiol-isomer-vapors from treated plants. The technic used was essentially that of David (1952). Lemon seedlings of 20 to 30 leaves or Black Valentine bean plants were treated topically at the base with thiono- or thiol-isomer. Above the site of application the plant was passed through a plexiglass plate and the stem sealed into the opening with wax. The plant was covered with a bell jar which fit tightly over the plate, and filtered air was drawn from the top of this jar through a tube passing through its top and extending to its bottom so that the air current passed up across the leaves. The exhausted air passed through a 50 ml. fritted glass bubbler filled with ice-cooled chloroform and then through a 250 ml. bubbler of benzene. At intervals the absorbant liquids in the bubblers were concentrated and assayed for radioactivity.

Four separate experiments were performed using this technic. Bean plants were treated with (a) 20 μl. of S^{35}-Systox (Sample A); (b) 10 μl. of P^{32}-thiono-isomer (Sample C); 10 μl. of P^{32}-thiol-isomer (Sample C); and a lemon seedling was treated with 10 μl. of S^{35}-Systox (Sample A). Assays for radioactivity were made after 24 hours and in several cases were continued over a period of 3 days. No trace of radioactivity was ever found in the chloroform or benzene from the bubblers although the leaves at the termination of each experiment contained from 50 to 300 γ/g. of thiono- and thiol-isomer-metabolites. These results are not in agreement with those of Tietz (1954) who considers that elimination of Systox exudates through the leaf-stomata provides an important means of detoxication. The variation in results is probably due to differences in plant species and dosage and method of application of the Systox.

SUMMARY AND CONCLUSIONS.—The comparative behaviors of radiotracer preparations of the thiono- and thiol-isomers of Systox have been investigated in bean and lemon plants. The isomers are readily absorbed by the roots and stems of lemon seedlings and translocated to the leaves in amounts toxic to the citrus red mite and greenhouse thrips. The translocated materials concentrate most strongly in the peripheral growing areas of the upper leaves, and the systemic behavior closely resembles that of schradan. Following

[7] Ripper, W. E. 1952. Systemic Insecticides. Paper presented to International Congress of Crop Protection, Paris.

Table 6.—Radio- and ChE-assay of active spots from chromatographs of chloroform extractives of leaves from bean plants topically treated with thiono- and thiol-isomers.

	R_f	TOTAL RADIO-ACTIVITY c.p.s.	ChE INHIBITION PER CENT
Thiol-isomer— 4 hrs.	0.03–0.09	233	0
	0.5 –0.57	3551	100
	0.84–0.90	1830	99
Thiol-isomer— 8 hrs.	0.03–0.09	600	0
	0.64–0.71	6970	100
	0.89–0.95	6661	100
Thiono-isomer— 24 hrs.	0.03–0.1	187	0
	0.54–0.61	189	64
	0.83–0.90	3952	89

topical application of the thiol-isomer to the stems of bean and lemon plants, radioactivity accumulated in the upper leaves from 5 to 10 times as fast as it did following the application of the thiono-isomer. Studies of the quantitative metabolism of the Systox-isomers in bean and lemon leaves by paper chromatography indicated a rapid metabolism of both isomers. In the bean plants 80 to 90 per cent of the total radioactivity in the leaves was in metabolized forms within 24 hours. Metabolism was slightly slower in lemon plants, but 97 to 100 per cent of the total radioactivity was in metabolized forms within 4 days. From the results of two independent sets of paper chromatographic studies with entirely different solvents and stationary phases, it appears that a single toxic metabolite comprises about 90 per cent or more of the initial metabolic products for each of the isomers.

Contact toxicity studies showed that the thiol-isomer is from 3 to 5 times as toxic as the thiono-isomer to the greenhouse thrips and citrus red mite. The LD_{100} of the thiono-isomer metabolite to these pests was estimated at about 300 γ/g. of leaf while that of the thiol-isomer metabolite was less than 40 γ/g. of leaf. The pure thiono-isomer is of low activity as an inhibitor of fly-brain ChE, but the thiol-isomer is highly active as are the principal metabolites of both isomers. Radioactive vapors could not be isolated from the leaves of bean or lemon plants topically treated on the stem by the tracer isomers of Systox.

LITERATURE CITED

David, W. A. L. 1951. Insecticidal-action studies with bis-dimethylaminophosphonus anhydride containing ^{32}phosphorus. Ann. Appl. Biol. **38**: 508–24.

David, W. A. L. 1952. Insecticidal-action studies with bis-dimethylamino fluorophosphine oxide containing ^{32}phosphorus. Ann. Appl. Biol. **39**: 203–10.

Fukuto, T. R., and R. L. Metcalf. 1954. Isomerization of 0,0-diethyl 0-beta-mercaptoethyl ethyl thionophosphate (Systox). In press. J. Amer. Chem. Soc.

Gage, J. C. 1953. A cholinesterase inhibitor derived from 0,0-diethyl 0-*p*-nitrophenyl thiophosphate *in vivo*. Biochem. Jour. **54**: 426–30.

Giang, P. A., and S. A. Hall. 1951. Enzymatic determinations of organic phosphorus insecticides. Anal. Chem. **23**: 1830–4.

Hartley, G. S., and D. F. Heath. 1951. Decomposition of radioactive octamethyl pyrophosphoramide in living plants. Nature **167**: 316.

Heath, D. F., D. W. J. Lane, and M. Llewellyn. 1952. Commercial octamethylpyrophosphoramide III. Decomposition of the insecticide in plants using phosphorus^{32} as a tracer. Jour. Sci. Food Agr. **3**: 60–9.

Hensel, J., A. E. Hewitt, U. M. Sheets, and R. C. Scott. 1954. Microestimation of demeton residues. Tech. Bull. Chemagro Corp.

March, R. B., R. L. Metcalf, and T. R. Fukuto. 1954. Paper chromatography of the systemic insecticides, demeton and schradan. Jour. Agr. Food Chem. **2**: 732–5.

Metcalf, R. L., and R. B. Carlson. 1950. Systemic pest control. Citrus Leaves **30**: 12–13, 26.

Metcalf, R. L., and R. B. March. 1952. Behavior of octamethyl pyrophosphoramide in citrus plants. JOUR. ECON. ENT. **45**: 988–97.

Metcalf, R. L., and R. B. March. 1953. Reversed phase paper chromatography of parathion and related phosphate esters. Science **117**: 527.

Schrader, G. 1952. The development of new insecticides. Angewandte Chemie. Monogr. No. **62**

Tietz, H. 1954. The penetrativity, the translocation, and the excretion of P^{32} marked systox in tall plants. Farbenfabriken Bayer.

Hazards Involved When Animals are Exposed to Organic Insecticidal Residues[1]

DWIGHT M. DELONG, *The Ohio State University, Columbus*, and PAUL LUDWIG, *Boyce Thompson Institute, Yonkers, New York*

During the past several years various experiments have been performed by many workers in an attempt to determine the toxicological effects to vertebrates of most of the newer organic insecticides. These experiments have been concerned with two approaches to this problem. Either the food was contaminated with known amounts of the insecticide, so that definite doses were fed to each animal daily, or periodic injections of these chemicals were made into the bodies of experimental animals. Conclusions drawn from laboratory data of this type have formed the basis for limiting or prohibiting the use of certain organic insecticides as sprays or fogs without apparent respect to the residues obtained under conditions of practical applications and the resultant experimentation with food contaminated in this manner.

As far as can be ascertained, no published data are available that show the amount of spray residue on exposed foods as a result of practical treatments, and there are no published results of the feeding of such food to experimental animals.

The experiments reported here were conducted to learn what would result when foods were contaminated in practical applications and these contaminated foods were fed exclusively to experimental animals.

MATERIALS AND METHODS.—A series of rooms was selected in a modern school building all of which were approximately the same size and which were constructed with the same types of materials. These were then treated with fog applications of certain percentages of chlordane, lindane, or Compound G 22008[2] at the rate of 2 fluid ounces per 1000 cu. ft. of space.

Before treatment 50 pounds of dog chow checkers were spread one layer thick on the floor of each room. After treatment each room was kept tightly closed for several hours, at the end of which time the dog chow checkers were returned to their respective containers and were removed. The rooms remained closed and were used for toxicological tests with flies. One hundred female green bottle flies, *Phaenicia sericata* (Meigen), were liberated in each room once a week to determine the percentage of mortality and the length of time required to obtain this mortality after liberating the flies.

The concentrations of sprays used were chlordane 1, 2, 3, and 7 per cent; lindane 0.5, 1, and 2 per cent; Compound G 22008 at a 5 per cent strength, and in combination with small percentages of chlordane and lindane. Applications were made with small fog machines which were reported in previous work (DeLong *et al.* 1952).

Residue deposits were determined by the use of sheets of pliofilm or cellophane 1½ by 3 feet in size, weighed before and after treatment, and placed on portions of the walls, ceiling, and the floor.

RESULTS.—Repeated samples showed that the residues in each of these locations were approximately the same and that the dispersal and distribution were rather equally affected by this method. The average residue was less than 5.0 mgs. per square foot of surface.

The data obtained from the tests with green bottle flies (*P. sericata*) showed a rather high (71 to 100 per cent) mortality for a period of 54 days, depending upon the material and dosage used. This was indicative that a sufficient amount of material was used to obtain a good insecticidal control.

The dog pellets which had been contaminated by the various treatments were fed to white rats beginning immediately after treatment. Each rat was isolated and fed five pellets (16.8 gms.) per day. Three replicates were used in the feeding experiments for each insecticidal treatment. The rats were fed for a period of five months upon this contaminated food alone and were furnished with an adequate supply of water. During the 150 days of feeding each rat consumed 55.8 mg. of poisonous residue, at the rate of 0.38 mg. per day. This was at the rate of

[1] Presented at the First Annual Meeting of the Entomological Society of America held at Los Angeles, California, December 7–10, 1953.

[2] 3-methyl-1-phenyl-pyrazolyl-(5)-dimethylcarbamate.

1.2 mg. per kilogram of body weight per day.

During the feeding tests two rats died, both of which were being fed untreated pellets. At the end of five months the rats were autopsied by Doctor Harry L. Reinhart, M.D., Professor of Pathology at the Ohio State University Medical School. The following is a brief statement of his report.

"I have completed the microscopic examinations of the viscera of the rats submitted by you and find no noteworthy pathology in any of the organs examined with reference to a possible toxic effect from any materials which have been administered. The organs examined from each rat are as follows: lungs, heart, stomach, liver, kidneys, spleen, and testes in male rats.

One noteworthy exception to the above was the presence of adenocarcinoma of one kidney of one rat. There were no evidences of metastases. There is no evidence that this tumor had anything to do with the experiments which you have been conducting. This rat was labeled #6B in our series. If you desire a more detailed report, I can furnish it, although practically all of the information would be negative."

Signed—H. L. Reinhart, M.D.
Dept. of Pathology

Additional Fog Applications.—In view of these experimental data and the work of Ingle (1953), Princi & Spurbeck (1951), and Alvarez & Hyman (1953), two rooms containing cultures of experimental animals were treated with fog applications of 7 per cent chlordane. In both cases the animal cages were infested with bed bugs, *Cimex lectularius* Linn., and with German cockroaches, *Blatella germanica* (Linn.). Animals exposed to these fog applications were rabbits, guinea pigs, white rats, mice, and poultry. Although the fog applications remained in a visible, smoke-like, phase in these rooms for more than an hour in each case, no injury was caused to any of these animals and no apparent reactions were observed.

Further to test the human injury theory of the extremely toxic and dangerous effects of chlordane which have been stated in writing by Lehman (1950) and Frings & O'Tousa (1950) and given to the press by several physicians belonging to the Medical profession, the senior author subjected himself to vapors of 7 per cent chlordane for 15-minute exposures at 3-day intervals for a period of 12 weeks during the summer of 1952 and again in 1953. Repeated, thorough medical examinations have shown no toxic effects whatsoever from this insecticide. This further verifies the work of Ingle upon the effects of chlordane vapor.

Conclusions.—The results of these experiments indicate that when certain of the restricted organic insecticides are used at practical dosage levels as fog applications, there is no evidence that either the vapors or the resulting residues would be harmful to man or animals, even if food materials were exposed and contaminated with insecticidal residues. All foods in markets are normally canned, packaged, sealed, and/or wrapped with cellophane.

Literature Cited

Alvarez, W. C., and S. Hyman, 1953. Absence of toxic manifestations in workers exposed to chlordane. A.M.A. Arch. Indust. Hyg. & Occup. Med. **8:** 480–3.

DeLong, D. M., G. M. Boush, and A. O. Lea. 1952. The comparative residual toxicity of fog applications of certain organic insecticides to house flies. Jour. Econ. Ent. **45**(2): 323–5.

Frings, Hubert, and T. E. O'Tousa, 1950. Toxicity to mice of chlordane vapor and solutions administered cutaneously. Science **111:** 658.

Ingle, L. 1953. The toxicity of chlordane vapors. Science **118:** 213–4.

Lehman, Arnold J. 1950. Some toxicological reasons why certain chemicals may or may not be permitted as food additives. Bul. Assoc. Food and Drug Officials. **14:** 82.

Princi, F., and G. H. Spurbeck. 1951. A study of workers exposed to the insecticides chlordane, aldrin, dieldrin. A.M.A. Archives Indus. Hyg. **3:** 64–72.

The Adsorption, Distribution, and Site of Action of DDT in DDT-Resistant and DDT-Susceptible House Flies Using Carbon^{14} Labelled DDT

E. J. LeRoux, *Entomology Division, Science Service, St. Jean, Quebec,* and F. O. Morrison, *Macdonald College, McGill University*

This study is a continuation and extension of the work of Fisher (1952) utilizing carbon^{14} labelled DDT prepared by Macdonald & Baker (1953) as a tool for tracing the path and rate of distribution of DDT or its metabolites within the body of topically treated house fly adults.

A DDT-susceptible strain of flies was established at the beginning of the study from wild flies collected in the laboratory. DDT-resistant flies were supplied in the pupal stage from the Science Service Laboratory at London, Ontario through the kindness of Dr. B. Smallman and Dr. R. W. Fisher. This strain had been inbred for many generations during which time the egg-laying adults were held in DDT coated cages. The original stock was obtained from Beltsville, Maryland.

Haemolymph samples for the study of the DDT-content of the blood were withdrawn through the coxal or cervical membranes by means of micro-pipettes. Pipettes were made by fitting a 22-gauge hypodermic needle, from which the end had been clipped, with a soft glass tubing 3 millimetres in diameter, which was fused onto the truncated needle in a flame and then drawn out to form a fine capillary tube. The joint between the needle and the syringe was reinforced with three coats of liquid solder and that between the glass and the needle cooled slowly and reinforced with "Hi-pyseal" cement. The fine end of the drawn out glass tube was filed to a sharp point. When this was inserted into the fly through the coxal or cervical membranes, pulling back the plunger arm of the syringe caused the blood to be drawn into the capillary tube. Approximately 1/16 millilitre of blood was taken from each fly. When the operation was carried out quickly to avoid the blood clotting the sample could be expelled from the capillary tube into a counting dish by means of the plunger. When it was desired to impede the circulation tight ligatures were tied around the cervix or pedicel using cotton thread (Morrison & LeRoux 1954).

All fly rearing, handling, immobilizing, and treating techniques were the same as those reported by Fisher (1952), LeRoux & Morrison (1954), and Morrison & LeRoux (1954). This applies also to all the equipment and techniques employed in the extracting and counting of the radioactive carbon from the body parts of treated flies. The total recovered activity in all instances, indicated that recovery was practically complete.

Most of the tests were conducted with a standard sized droplet of the DDT-benzol solution. A 1 per cent (weight on volume) solution was used. The droplets were produced by moving the ratchet arm of the microdrop machine through 11 notches. Fisher (1952) estimated the DDT content of one such droplet to be 2 micrograms. He based his estimates on mechanical measurement of dilute droplet volume. Morrison & LeRoux (1954) using the measured activity of such droplets as a guide considered this estimate about right. More carefully determined calculations using accurate estimates of the counter efficiency indicate that this earlier estimate was about 25 per cent too high. Individual droplets were collected from time to time as the work progressed and transferred after evaporation to the supersaturated state to counting dishes containing 0.5 ml. of benzol then evaporated down and counted as were the extracts. Table 1 gives these results.

Macdonald & Baker (1953) give the specific activity of the DDT they prepared as 62,000 counts per minute per milligram. No mention is made of the efficiency of the counter they used but College records show it to have been 1.87 percent. The efficiency of the counter used by the writers was 6.4 per cent on the average. Calculated from these figures the DDT used would be expected to give 212 c.p.m. per microgram on the counter

This investigation was financed in part by a Canadian Industries Limited fellowship to the senior author (1951–53), and in part by a grant-in-aid from the Canadian Research Council. It has been submitted in partial fulfilment of the requirements for a Ph.D. degree at McGill University.
Macdonald College Journal Series No. 352.

used. The average 11-notch droplet gave 330 c.p.m. This count would be expected from 1.55 micrograms. The standard droplet is therefore referred to in this paper as a 1.5-microgram droplet.

Droplets containing less than 1½ micrograms of DDT could be produced by reducing the number of notches through which the activating or ratchet arm of the machine moved to less than the 11 notches. Larger droplets could be similarly produced by increasing the number of notches. However, droplets produced by a movement of less than three notches evaporated to a size too small to handle. The same result would be expected if one started with a less concentrated solution of DDT because the final size of the supersaturated droplet depends on the non-volatile solute present. This limits the possible individual dosages to a minimum of about 0.3 microgram of DDT. To overcome this limitation an innocuous non-volatile filler with physical characteristics similar to DDT was sought. The ortho-para-analogue of DDT served admirably. Droplets prepared from a 1 per cent solution of this chemical behaved physically identically with those of DDT. When such supersaturated droplets, which by analogy contained 1½ micrograms of the ortho-para-analogue, were applied directly to the brain inside the heads of 180 DDT-susceptible flies the mortality (20 per cent) was not significantly different from that in non-treated checks with the probosces removed. DDT at one fifth that dosage produced 100 per cent mortality of both strains. When it was desired to reduce the dosage to 0.05 per cent micrograms standard 11-notch droplets were prepared from a 1 per cent solution made with 97 parts ortho-para- and 3 parts para-para-DDT.

Flies from which the probosces were removed at the base and the connective membranes which normally stop up the opening cleared away with a needle, suffered less than 20 per cent mortality when kept for 24 hours in a high humidity chamber. The operation exposed the internal tissues of the head and made it possible to apply the DDT droplet directly inside the head cavity on the supra-oesophageal ganglion itself.

Investigation of the effect of the same dosage applied over different integumental areas was accomplished by comparing the effects from droplets applied directly from the machine before evaporation to the supersaturated state with those from droplets evaporated down and put on with glass applicators. The former dilute droplets spread over a much larger area of integument. Counts made directly on three droplets collected from the machine (dilute) and three evaporated down (supersaturated) gave average activities of 314 c.p.m. for the former and 323 c.p.m. for the latter. These counts are sufficiently similar to the average secured from the earlier tests with evaporated droplets to indicate no appreciable loss in handling with the glass applicators and to make treatments with dilute and supersaturated droplets comparable except for the additional benzol present and the tendency to spread over a larger area shown by the dilute droplets.

Table 1.—Average activity in counts per minute of 11-notch droplets produced by the microdrop machine from 1 per cent DDT solution.

Number of Droplets	Counts per Minute per Drop
5	356
5	320
5	328
5	346
5	331
5	337
5	314
5	320
5	318
Totals 45	2972
Average c.p.m. per drop	330 ± 14

Studies were made of the distribution of DDT from topical application to the leg, labella and gena of susceptible flies as affected by the time during which the applied dosage was allowed to act. Similar studies were made using resistant flies and making application to the leg and labella. The effects of ligation on penetration and distribution were studied in susceptible flies. The respired air, faeces, haemolymph, head-integument, and brain tissue were checked for activity. Using nonactive DDT extensive tests were made on the effects on the mortality of both resistant and susceptible flies, of the locus of application, and time of action. The importance of the area of application, and time of action, was checked on susceptible flies. The influence of ligating on

Table 2.—Percentage radioactivity recovered after 24 hours from various body portions of 4-day-old, male, DDT-susceptible, house fly adults treated topically on the tibiofemoral membrane of one metathoracic leg[1] with 1.5 micrograms of C^{14} labelled pure para-para-DDT.

Duration of Exposure (Hours)	Number Treated	Percentage Radioactivity Recovered from: Treated Leg	Head	Thorax, Wings, and Legs	Abdomen
0.083	10	95.0	1.5	1.5	2.0
.25	25	95.0	1.5	2.0	1.5
.5	50	95.0	1.5	2.0	1.5
1	5	95.0	1.0	2.0	2.0
2	5	95.0	1.0	2.0	2.0
4	70	86.0	3.0	7.0	4.0
8	15	71.0	3.0	16.0	10.0
12	15	67.0	5.0	17.0	11.0
24	60	65.5	5.5	18.0	11.0
30	30	34.0	6.0	40.0	20.0

[1] The treated legs were excised at the coxal joint to terminate the exposure.

mortality and the importance of the DDT reaching the nervous tissue of the head was also investigated.

RESULTS.—The results of the experiments on which this paper is based are presented in tables 2 to 13, inclusive.

DISCUSSION.—The distribution of DDT and (or) its metabolites in the tissues of topically treated flies is influenced by the length of time the applied dosage remains on the integument; the area of integumental surface over which the dosage is originally spread; the locus of application on the integument; the genetic strain of fly used; the time of death, should it ensue, and any factor which slows down or prevents circulation of the haemolymph. Though all these factors except fly strain and impeding circulation appear to influence the rate of penetration rather than the final distribution, they may influence observed mortalities because they influence the rapidity of the buildup of the DDT-concentration in different body regions, and the concentration in certain regions appears to be a critical factor. Fly strain and impeding of the circulation directly influence the amounts of DDT which can reach and accumulate in certain regions.

Duration of contact.—When DDT (Table 2) was applied to the leg of susceptible flies and allowed to remain there for varying periods of time DDT (activity) was steadily lost from the treated leg to the rest of the body over a 30-hour period. Lindquist *et al.* (1951b) also found that continued penetration resulted after treatment of house flies with DDT. At the end of 30 hours the results of the writers' investigations show that 66 per cent of the applied dosage of 1½ micrograms was gone from the leg. Hoffman *et al.* (1952) and Lindquist *et al.* (1951a) report a somewhat smaller proportion of larger dosages as having penetrated in similar periods. Table 2 shows that other parts of the body accumulated the radioactivity as it left the leg. The greatest accumulation occurred in the thorax, probably because of its proximity, and as will be noted later, because it possesses a large integumental area and integument appears to have an affinity for DDT or its metabolites.

Area of contact.—When the topical application of DDT was spread over a larger area of the integument of the leg distribution was more rapid (Table 3), 2 to 4 hours sufficing to bring about as great accumulation in most regions of the body as was effected in 24 hours from point application.

Locus of application.—Penetration and distribution from the labella was continuous as it was from the leg but at a more rapid rate (Table 5). From this locus the amount accumulating in the head built up in 30 minutes to a level as high as that reached in 4 hours from the leg-locus due to the more rapid distribution and to the proximity of the head to the point of application.

Distribution from the gena was possibly slightly slower than from the labella but more rapid than from the leg (Table 5).

Table 3.—Percentage radioactivity recovered after 24 hours from grouped body portions of 4-day-old male DDT-susceptible house fly adults treated topically with 1.5 micrograms of C^{14} labelled para-para-DDT.[1]

How Applied	Duration of Exposure (Hours)	Percentage Radioactivity Recovered from: Treated Leg	Head	Thorax, etc.	Abdomen
Drop localized on leg[2]	0.5	96.0	0.5	2.0	1.5
	1	95.0	1.0	2.0	2.0
	2	96.0	1.0	1.5	1.5
	4	90.0	3.0	4.0	3.0
Drop spread[3]	.5	90.0	0.5	9.0	0.5
	1	82.0	1.5	14.0	2.5
	2	63.0	3.0	25.0	9.0
	4	30.0	8.0	45.0	17.0

[1] The treated leg was excised at the end of the desired exposure period. Data based on 10 flies for each period.
[2] Dosage was pin-pointed as a supersaturated drop.
[3] Dosage was allowed to spread over a large area of the leg as a droplet of dilute solution in benzol.

Table 4.—Percentage radioactivity recovered from grouped body portions of 4-day-old male DDT-susceptible house fly adults treated topically with 1.5 micrograms of C^{14} labelled para-para-DDT.[1]

State of Flies	Number Treated	Examined After (Hours)	Percentage Radioactivity Recovered from: Treated Leg	Head	Thorax, etc.	Abdomen
alive	5	24	48	7	32	13
dead	6	24	59	5	21	15
alive	7	30	25	7	46	22
dead	7	30	43	5	35	17

[1] Treated on the tibio-femoral membrane of one metathoracic leg and segregated at time of dissecting into dead and living flies.

Table 6.—Percentage radioactivity recovered after 24 hours from grouped body portions of 4-day-old, male, DDT-resistant house fly adults treated topically with 1.5 micrograms of C^{14} labelled para-para-DDT.[1]

Locus Treated	Number Treated	Percentage Radioactivity Recovered from: Treated Leg	Head	Thorax, etc.	Abdomen
leg	90	96.5	0.5	1.5	1.5
labella	40	91.5	3.0	3.0	2.5

[1] The dosage was allowed to act for the full 24 hours.

Death.—Penetration and distribution continued after the death of the flies but at a slower rate (Table 4). The result bears out those reported by Sternburg *et al.* (1950), Hoffman *et al.* (1952), and Tahori & Hoskins (1953a).

Strain.—The DDT-resistant Beltsville strain of flies moved the active carbon (DDT?) from the point of application to other regions of the body much more slowly than did the susceptible flies (Table 6) regardless of the locus of application. The heads of DDT-resistant flies accumulated less than 1 per cent of the $1\frac{1}{2}$-microgram dosage applied to the legs in 24 hours, while those of susceptible flies accumulated 5.5 per cent in their heads in the same period (Table 2). From the labella-locus the heads of susceptible flies accumulated 3 per cent of the applied dosage in 30 minutes (Table 5) while the heads of resistant flies required 24 hours to accumulate the same amount (Table 6).

Role of haemolymph.—A tight ligature at any point around the body retards or prevents haemolymph circulation. Thus DDT-susceptible flies ligated about the waist of the abdomen (pedicel) or about the neck (cervix) and then treated, moved the active carbon compounds from the point of application more slowly than before and accumulated little or no activity on the side of the ligature opposite to the locus of application (Table 7). This suggests that DDT or its metabolites are continually picked up from the point of application by the haemolymph, transported to all body tissues and absorbed by them. This conclusion is further borne out by the finding of activity from topically applied C^{14} labelled DDT in the haemolymph of the cervical region as soon as 30 seconds after application to the leg (Table 8). Though the size of haemolymph samples probably varied a little the titre of activity in the haemolymph appeared to remain fairly constant over a 24-hour period. The blood appears to transport but not to accumulate the activity. Tahori & Hoskins (1953b) claim a similar role for the haemolymph.

Roan *et al.* (1950) and Ball & Beck (1951) found that insect haemolymph distributed but did not accumulate to any extent various oil soluble phosphoric acid esters with which they worked. Buck *et al.* (1952) reported that ligating *Phormia* larvae behind the brain retarded the high oxygen uptake characteristic of DDT intoxication.

Affinity for integument.—Richards

Table 5.—Percentage radioactivity recovered after 24 hours from grouped body portions of 4-day-old, male, DDT-susceptible house fly adults treated topically with 1.5 micrograms of C^{14} labelled para-para-DDT on the labella or gena.[1]

Duration of Exposure (Hours)	Number Treated	Locus Treated	Percentage Radioactivity Recovered from: Proboscis	Head	Thorax, etc.	Abdomen
0.5	40	labella	91.5	3.0	3.0	2.5
1	20	labella	86.0	8.0	3.0	3.0
4	20	labella	64.0	10.0	15.0	11.0
24	40	labella	26.0	11.0	33.0	30.0
24	20	gena		69.0	20.8	10.2

[1] The labella was excised at the base to terminate the exposure.

Table 7.—Percentage radioactivity recovered after 24 hours from the grouped body parts of 4-day-old, male, DDT-susceptible, house flies, tightly ligated then treated with 1.5 micrograms of C^{14} labelled DDT.[1]

Ligated at	Locus Treated	Number Treated	Percentage Radioactivity Recovered from:			
			Treated Leg	Head	Thorax, etc.	Abdomen
pedicel	leg	5	72.2	3.0	24.0	0.8
cervix	leg	30	76.0	0.3	12.2	11.5
cervix	labella	25		97.7[2]	2.1	0.2

[1] Dosage allowed to act for the full 24 hours.
[2] Area of application included with head.

(1951), Sternberg *et al.* (1950), and Hoffman *et al.* (1952) have reported that chitin or some other material in insect integument absorbs DDT or its metabolites which tend to accumulate in this tissue. The writer found that the integument of the head contained most of the activity accumulated in that organ (Table 8). It is possible that with the technique used in the present work the liquid tissues of the head may have dried onto the integument rather than onto the internal structures.

Activity in faeces.—Small amounts of activity were recovered from the faeces of flies treated topically with C^{14} labelled DDT (Table 8). The amount eliminated in this way did not appear to be influenced by the locus of application but was considerably larger in the DDT-resistant strain than in the DDT-susceptible strain. Though probably not an important factor this power of elimination would appear to be coupled with reduced penetration and possibly detoxification (not tested here) and still other factors in the complex of differences which make up resistance in the DDT-resistant strain tested. Slight amounts of DDT or its metabolites have been reported in house fly faeces by Sternburg & Kearns (1950), Perry & Hoskins (1951), and Roth & Lindquist (1953).

Expired air.—In keeping with the findings of Roth & Lindquist (1953), who found that no radioactivity could be demonstrated in the carbon dioxide collected from DDT-treated flies, the writer failed to detect any activity in the expired air of flies topically treated with active DDT. In view of the difficulty of breaking the DDT molecule down to CO_2 and the lack of any evidence of enzymes

Table 8.—Percentage radioactivity recovered at different intervals of time from the respired air,[1] faeces, haemolymph samples, head-integument, and nervous tissue of the heads, of 4-day-old, male, adult house fly strains treated with C^{14} labelled DDT.

Locus Treated	Duration of Exposure	Number Treated	Percentage Radioactivity Recovered from:					
			Body	Excreta	Haemolymph		Head Integument	Nerve Tissue
					Coxal	Cervical		
leg	24 hours	25						
leg	4 hours	5	99.3	0.7				
leg	24 hours	30	99.1	0.9				
labella	30 minutes	5	99.6	0.4				
leg[2]	24 hours	70	98.0	2.0				
leg	30 seconds	10	99.0		1.0			
leg	1 minute	5	98.8		1.2			
leg	30 seconds	10	99.0			1.0		
leg	1 minute	5	98.4			1.6		
leg	2 minutes	5	97.7			2.3		
leg	5 minutes	10	98.5			1.5		
leg	30 minutes	10	98.9			1.1		
leg	4 hours	10	99.0			1.0		
leg	24 hours	10	99.2			0.8		
labella	30 minutes	15	96.0				4.0	
labella	30 minutes	15	99.0					1.0

[1] None recovered from respired air.
[2] From DDT-resistant strain; all others from DDT-susceptible strains.

Table 9.—The percentage mortality observed when 4-day-old, DDT-susceptible male, house fly adults were treated topically with varying amounts of DDT.

Dosage (μgs.)	Locus Treated	Number Treated	Percentage Mortality After 24 Hours	
			Treated	Untreated Check
0.3	leg	35	11	6
0.6	leg	85	29	9
1.5[1]	leg	20	70	15
3.0	leg	20	100	35
4.5	leg	20	100	25
6.0	leg	20	100	30
0.3	labella	40	15	9
0.6	labella	65	37	10
0.9	labella	40	60	10
1.5	labella	140	87	7

[1] See also table 10 for mortalities with large numbers at this dosage.

Table 10.—Percentage mortality observed when 4-day-old, male, house flies of different strains were treated with 1.5 micrograms of DDT applied topically to different loci of action.

Fly Strain	Locus Treated	Number Treated	Percentage Mortality After 24 Hours	
			Treated	Untreated Check
susceptible	leg	650	68	17
susceptible	labella	140	87	7
susceptible	gena	20	80	30
resistant	leg	90	25	12
resistant	labella	20	60	7

which can carry the break down to that point this is not surprising.

Distribution and mortality.—The observed mortality appeared to be closely correlated with the distribution of radioactivity in the bodies of the flies, especially with the level of activity accumulating in the head. A dosage of 1½ micrograms of DDT applied to the leg of DDT-susceptible flies produced in 24 hours an average mortality of 68 per cent (Table 10). At that time interval, from 3 per cent to 5 per cent of the activity had reached the insect head. Larger dosages (Table 9) or equal dosages with larger areas of contact (Table 10) gave more rapid and higher mortality figures. Greater areas of contact led also to greater accumulation in the head (Table 3). Smaller dosages, as would be expected, gave reduced mortalities (Table 9). Little increase in mortality resulted from applications left in contact with the integument more than 4 hours (Tables 9, 10, 11), at which time 3 per cent of the activity was in the head (Table 2).

One and one-half micrograms of DDT applied to the labella of susceptible flies and left in contact for 30 minutes caused greater mortality (checked 24 hours after application) than a similar application allowed to remain on the leg for 4 hours. Little increase in mortality from continuous contact on the labella for greater than 30 minutes (Table 11) was obtained. The concentration in the head from the labella-locus at 30 minutes was again 3 per cent (Table 5). Lower dosages on the labella-locus of susceptible flies also gave reduced mortalities (Table 9). Application to the gena was as effective as application to the labella (Table 10).

DDT-resistant flies treated on the leg with 1½ micrograms of DDT showed 25 per cent mortality in 24 hours, while those treated on the labella showed 60 per cent mortality in the same time (Table 10). Since none of these mortalities have been corrected for deaths in the untreated checks (12 per cent in the case of the leg

Table 11.—Percentage mortalities observed when 4-day-old, DDT-susceptible, male, house fly adults were treated topically on the leg or labella.

Duration of Treatment[1]	Locus Treated	Droplet Type[2]	Number Treated	Percentage Mortality After 24 Hours	
				Treated	Untreated Check
15 minutes	leg	concentrated	35	40	20
30 minutes	leg	concentrated	50	40	6
4 hours	leg	concentrated	120	81	26
30 seconds	leg	dilute	20	35	20
30 minutes	leg	dilute	20	45	25
2 hours	leg	dilute	20	75	15
15 minutes	labella	concentrated	100	27	6
30 minutes	labella	concentrated	133	83	9
24 hours	labella	concentrated	140	87	7

[1] Amputation of treated parts at intervals limited the time of action allowed.
[2] Droplets contained 1½ micrograms of DDT either in a concentrated droplet of supersaturated benzol solution which did not spread or in a more dilute benzol solution which spread over much of the leg.

Table 12.—Percentage mortalities observed when 4-day-old, DDT-susceptible, male, house fly adults were decapitated, ligated at the cervix or pedicel, or ligated and treated with 1.5 micrograms of DDT.

Locus Treated	Dosage (μgs.)	Other Treatment	Number Treated	Percentage Mortality After 24 Hours	
				Treated	Untreated Check
	0	decapitated	100	100	0
	0	cervix ligated	50	0	0
leg	1.5	cervix ligated	45	31	13
leg	1.5	pedicel ligated	45	60	15
labella	1.5	cervix ligated	45	88	14

application) the 25 per cent figure can be considered as very low. The differential between the mortalities produced by equal dosages on the legs of DDT-resistant and DDT-susceptible flies (25 per cent and 68 per cent mortality, respectively) was much greater than that between the mortalities produced by the same dosage on the labella of the same strains (60 per cent and 84 per cent mortality, respectively). The accumulation of activity in the heads of DDT-resistant flies after 24 hours from the leg-locus was 0.5 per cent while the accumulation in the head from the labella-locus was 3 per cent (Table 6).

Confirmation of the importance of the head as a site of action comes from the effects of ligatures on mortality and the correlation of these effects with the activity accumulating in the head. Cervical ligatures on DDT-susceptible flies reduced the mortality from the action of 1½ micrograms of DDT on the leg for 24 hours to 31 per cent (Table 12). Ligatures on the pedicel reduced (only slightly) the mortality to 60 per cent. Cervical ligatures reduced the DDT reaching the head to 0.3 per cent, and those on the pedicel (tested only once) allowed 3 per cent to reach the head, as compared to 5.5 per cent or better when no ligature was used (Table 2). Ligatures even at the pedicel appear to retard circulation. When ligatures were applied to the cervix and treatment made on the labella, mortality was not reduced (83 per cent mortality) (Table 12).

Still further evidence as to the role played by the head can be seen in the 100 per cent mortality of both strains produced when 3/10 micrograms (approximately 20 per cent of the standard topical dosage of 1½ micrograms) of DDT were administered directly within the head cavity (Table 13). When 0.05 microgram (about 3 per cent of the standard topical dosage of 1½ micrograms) was administered directly within the head cavity it killed 66 per cent of the DDT-resistant and 84 per cent of the DDT-susceptible flies in 24 hours. These mortalities correspond very closely to those produced by the 1½-microgram dosage on the labella of the two strains. There is still a difference in the susceptibility of the two strains but the differential has further narrowed.

Table 13.—Percentage mortalities observed when 4-day-old male, house fly adults of both strains were treated with different dosages of ortho-para- and para-para-DDT.[1]

Dosage o-p-DDT (μgms.)	Dosage p-p-DDT (μgms.)	Fly Strain	Number Treated	Percentage Mortality After Hours Indicated				
				Treated				Check
				4	8	10	24	24
1.5	0.0	susceptible	120				20	16
0.0	0.3	susceptible	80				100	00
1.45	0.05	susceptible	110	8	34	60	84	
1.5	0.00	resistant	120				17	11
0.0	0.3	resistant	80				100	10
1.45	0.05	resistant	110	4	16	42	66	

[1] Applied as supersaturated droplets of benzol solution directly to the nervous tissue of the head through an opening created by removing the proboscis and its basal membranes.

This appears in keeping with the conclusion of Pratt & Babers (1953) that the ganglion tissue of DDT-resistant flies is not as susceptible as that of DDT-susceptible flies and hence that differential detoxification is not the full explanation of susceptibility differences.

Effect of locus on LD 50.—One can conclude from the penetration and mortality data that if approximately 3 per cent of the applied dosage of 1½ micrograms of DDT and (or) metabolites reached the head and accumulated there over 50 per cent mortality resulted in both strains with a little higher mortality in the susceptible strain. The amount that reaches the head in a given length of time is greatly influenced by the locus of application. The observed LD 50 will then be influenced by the locus of application, being less if determined from application to the labella than from application to the leg and least if determined by application to the internal tissues of the head. This agrees with the findings of Lindquist *et al.* (1951a). Comparisons of DDT-resistant strains based on LD 50's will also be greatly influenced by the locus used, the difference being minimized by application to the internal tissues of the head and maximized by application to the leg. It would appear too that the conclusions of Tobias & Kollros (1946), that the LD 50 for DDT by topical application and injection are about the same and the further conclusion of Brown (1951), that DDT is unique in that it behaves as if the integument offered no barrier, are the result of injection methods which failed to get the chemical directly to the seat of action. The greater sensitivity of test animals when treated at or near the site of action may offer bioassay methods of greatly increased sensitivity.

CONCLUSIONS.—The locus of application of DDT topically applied to the house fly adult greatly influences the rate of penetration, distribution, and accumulation at the site of action.

Distribution of DDT from the point of application to other parts of the insect body is by way of the haemolymph. The haemolymph itself does not accumulate DDT. Other tissues and organs absorb the DDT or its metabolites from the haemolymph accumulating it. This is especially true of the integument.

The area of contact bears a direct relation to the rate at which DDT penetrates into the haemolymph and is distributed to the body parts. Distribution of DDT from the point of application continues at a reduced rate in dead flies.

Some organ or product in or produced within the head of the house fly adult appears to be the site of action of DDT. In all flies tested a concentration of 0.05 microgram of DDT (or metabolites) in the head resulted in over 50 per cent mortality.

The DDT-resistant strain of house flies used absorbed externally-applied DDT from all tested loci much more slowly than the susceptible strain employed.

A dosage of 0.05 microgram of DDT applied directly within the head had an effect on both the DDT-susceptible and DDT-resistant flies equal to that produced by 1½ micrograms applied externally on the leg.

DDT resistance in house flies appears to be a complex phenomenon due to slower penetration and distribution (especially to the head), more rapid elimination in the faeces, and some other factors which are probably not entirely detoxification factors since the application of DDT directly to the site of action still produces less mortality in this strain.

LD 50's calculated from the topical application of DDT are influenced by the locus of application. The closer the locus is to the site of action (in the case of the house fly the inside of the head) the lower the observed LD 50.

Comparisons of strain susceptibility to DDT varied with the locus of DDT application. The nearer the point of application to the site of action the less the observed susceptibility differential. The greater susceptibility of animals treated near or on the site of toxic action offers a method of stepping up the sensitivity of bioassay methods.

LITERATURE CITED

Ball, H. J., and S. D. Beck. 1951. The role of the circulatory and nervous systems in the toxic action of parathion. JOUR. ECON. ENT. **44**: 558–64.

Brown, A. W. A. 1951. Insect control by chemicals. New York, John Wiley and Sons Inc.

Buck, J. B., M. L. Keister, and I. Posner. 1952. Physiological effects of DDT on *Phormia* larvae. Ann. Ent. Soc. Amer. **45**: 369–84.

Fisher, R. W. 1952. The importance of the locus of application on the effectiveness of DDT for the house fly, *Musca domestica* L. (Diptera: Muscidae). Can. Jour. Zool. **30:** 254–66.
Hoffman, R. A., A. R. Roth, A. W. Lindquist, and J. S. Butts. 1952. Absorption of DDT in house flies over an extended period. Science **115:** 312–3.
LeRoux, E. J., and F. O. Morrison. 1954. Dosage of DDT needed to kill a house fly. JOUR. ECON. ENT. **46:** 1109–10.
Lindquist, A. W., A. H. Madden, and H. O. Schroeder. 1945. Effect of temperature on knockdown and kill of house flies exposed to DDT. JOUR. ECON. ENT. **38:** 261–4.
Lindquist, A. W., A. R. Roth, W. W. Yates, and R. A. Hoffman. 1951a. Use of radioactive tracers in studies of penetration and metabolism of DDT in house flies. JOUR. ECON. ENT. **44:** 167–72.
Lindquist, A. W., A. R. Roth, and R. A. Hoffman. 1951b. The distribution of radioactive DDT in house flies. JOUR. ECON. ENT. **44:** 931–4.
Macdonald, R., and B. E. Baker. 1953. Synthesis C^{14} labelled DDT. Can. Jour. Chem. **31:** 517–9.
Morrison, F. O., and E. J. LeRoux. 1954. House fly head as site of lethal action of DDT. Can. Jour. Agr. Res. **34:** 316–8.
Perry, A. S., and W. M. Hoskins. 1951. Detoxification of DDT as a factor in the resistance of house flies. JOUR. ECON. ENT. **44:** 850–7.
Pratt, J. J., and F. H. Babers. 1953. Sensitivity to DDT of nerve ganglia of susceptible and resistant house flies. JOUR. ECON. ENT. **46:** 700–2.
Richards, A. G. 1951. The integument of arthropods. Minneapolis, Minnesota. University of Minnesota Press.
Roan, C. C., H. E. Fernando, and C. W. Kearns. 1950. A radiobiological study of four organic phosphates. JOUR. ECON. ENT. **43:** 319–25.
Roth, A. R., and A. W. Lindquist. 1953. Effect of temperature and the activity of house flies on their absorption of DDT. JOUR. ECON. ENT. **46:** 127–30.
Sternburg, J. C., W. Kearns, and W. N. Bruce. 1950. Absorption and metabolism of DDT by resistant and susceptible house flies. JOUR. ECON. ENT. **43:** 214–9.
Sternburg, J. C., and C. W. Kearns. 1950. Degradation of DDT by resistant and susceptible strains of house flies. Ann. Ent. Soc. Amer. **43:** 444–58.
Tahori, A. S., and W. M. Hoskins. 1953a. The absorption, distribution and metabolism of DDT in DDT-resistant house flies. JOUR. ECON. ENT. **46:** 302–6.
Tahori, A. S., and W. M. Hoskins. 1953b. The absorption, distribution and metabolism of DDT in DDT-resistant house flies. JOUR. ECON. ENT. **46:** 829–37.
Tobias, J. M., and J. J. Kollros. 1946. Relation of absorbability to the comparative toxicity of DDT for insects and mammals. Jour. Pharmacol. Exptl. Therap. **88:** 400.

The Synthesis and Chromatographic Purification of Radioactive Allethrin

FRED ACREE, JR., C. C. ROAN,[1] and FRANK H. BABERS, *Entomology Research Branch, Agr. Res. Serv,. U.S.D.A.*

dl-cis,trans-C^{14}-Allethrin (*dl*-allethrolone ester of *dl-cis,trans*-2-C^{14}-chrysanthemumic acid) has been prepared to facilitate a study of the penetration and metabolic fate of toxic esters of chrysanthemumic acid in connection with their toxicological and resistance phenomena in house flies and cockroaches. Although Pellegrini *et al.* (1952) synthesized randomly labeled pyrethrins by growing pyrethrum flowers in an atmosphere of C^{14}-labeled carbon dioxide, so far as is known, this is the first successful synthesis of a radioactive pyrethrin-type insecticide labeled in a single, known position.

The synthesis was accomplished by methods already well established for the preparation of unlabeled allethrin. Three practice runs starting with unlabeled glycine were made to establish slight modifications of the published procedures, and the apparatus and technique necessary not only to eliminate the isolation of some of the intermediates, but also to permit an efficient and safe handling of the radioactive materials.

Briefly, 2-C^{14}-glycine[2] was converted to ethyl 2-C^{14}-glycinate hydrochloride, from which ethyl diazo-2-C^{14}-acetate was prepared. When condensed with 2,5-dimethyl-2,4-hexadiene, the latter compound produced ethyl *dl-cis,trans*-2-C^{14} chrysanthemumate, which was hydro-

[1] Now with Kansas State College, Manhattan.
[2] Obtained from Isotope Specialties Co., Glendale, Calif., on authorization from the Atomic Energy Commission.

lyzed to *dl-cis,trans*-chrysanthemumic acid. Because an investigation on the resolution of the labeled acids is planned in the hope of providing some of the labeled isomeric allethrins for study, only 100 mg. of the racemate was esterified by way of the acid chloride with an excess of *dl*-allethrolone to yield the crude *dl-cis,trans*-C^{14}-allethrin.

Owing to the size of the sample prepared, partition chromatography offered the best means for purifying and identifying the *dl-cis,trans*-C^{14}-allethrin. Oiwa *et al.* (1952a) employed this means for purifying the unlabeled product and referred to previous work (Oiwa *et al.* 1952b) without giving any details of procedure. Harris[3] studied the partition of a commercial sample containing 93.9 per cent of unlabeled *dl-cis,trans*-allethrin (EDA method, Hogsett *et al.* 1953) between *n*-hexane and nitromethane on silicic acid. He found that the chrysanthemumic acid and anhydride fractions preceded the allethrin fraction from the column, that the allethrolone and acid chloride remained on the column, that the allethrin fraction represented a 91.9 per cent recovery of the sample and 98 per cent of the allethrin present, and that the tailings of the allethrin fraction represented an additional 1.5 per cent recovery.

Results of tests of toxicity to house flies made on fractions furnished by Harris confirmed the high purity of the allethrin fraction and showed that only the allethrin fraction and the tailings were toxic (40 per cent mortality, 0.1 microgram applied topically), the latter being of a much lower order (30 per cent mortality, 10-microgram dose).

Harris' procedure was used with the unlabeled allethrin sample from one of the practice runs before the labeled allethrin sample was chromatographed. The results of these two runs were comparable and substantiated those obtained by Harris except there was an absence of acid chloride. The allethrin fraction (fraction C), yielded from the second run the labeled allethrin, as shown by ultraviolet absorption, radiometric, and toxicity measurements. The ultraviolet absorption was essentially the same as that of a known sample of *α-dl-trans*-allethrin, as shown in figure 1, an indication that the product contained approximately 98 per cent *dl-cis, trans*-C^{14}-allethrin. Studies are under way to determine the validity of this assumption, as well as the nature of the other components separated from the column. In working with these smaller quantities, the acid-anhydride fraction was resolved into two nontoxic fractions. The tailings also yielded two fractions; both exhibited a low order of toxicity, which seems to indicate, in connection with Harris' work, that different lots of synthetic *dl-cis,trans*-allethrin contain different quantities of from 1 to 2 per cent of two artifacts that analyze for allethrin by the EDA method. The finished column was extruded, extracted, and found to be free of toxic material. When scanned, the extracted sections of the column appeared to be essentially free of radioactivity.

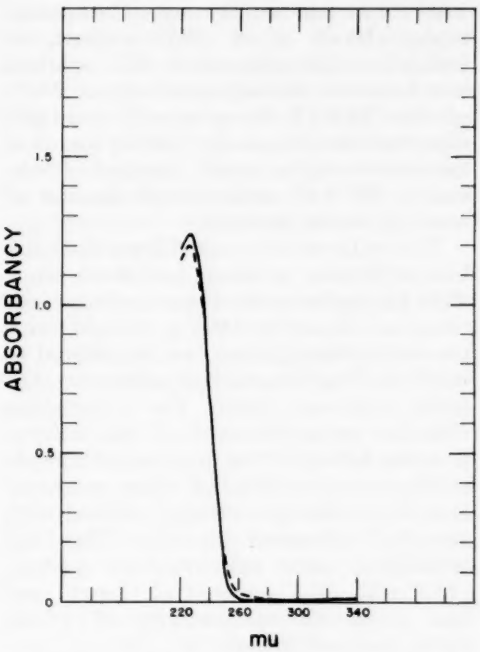


FIG. 1.—Ultraviolet absorption curves. ——— *α-dl-trans*-allethrin; - - - - Fraction C, *dl-cis,trans*-C^{14}-allethrin. Solvent: absolute ethanol.

Ethyl 2-C^{14}-glycinate hydrochloride.—Two millicuries (217.5 mg.) of commercially prepared 2-C^{14}-glycine was transferred, in small portions of water with a bulb pipette, from the shipping vials into a 25-ml. jointed flask. The glass could not be washed to less than approximately

[3] Thomas H. Harris, Plant Pest Control Branch, Agricultural Research Service, U. S. Department of Agriculture, unpublished information, for whose suggestions and technical assistance the authors express appreciation.

1700 c.p.m. per vial. By paper chromatography (Block *et al.* 1952 solvent, *n*-butanol-acetic acid-water) the solution was found to consist essentially of 2-C^{14}-glycine (Rf 0.17, the same as for pure glycine run simultaneously) but it was contaminated with a small quantity of substance (Rf 0.27) and a small amount of water-insoluble material.

The water was removed from the solution at 12 mm. pressure, and the residue, after having been dried in a vacuum desiccator and diluted to 2.027 g. (27 mM) with pure unlabeled glycine, was converted to ethyl 2-C^{14}-glycinate hydrochloride (Organic Syntheses, 1943). The dry residue obtained upon removal of the solvent from the filtrate of the first crop of crystals (3.36 g.) yielded 180 mg. when recrystallized from absolute ethanol diluted with an equal volume of dry ether. The total crystalline ester amounted to 3.54 g. (25.5 mM, 94.4 per cent of theory) and had a specific radioactivity of 16,560 c.p.m. per milligram.

The final filtrate contained radioactive material equivalent to about 4 mg. of ester.

dl-cis-trans-2-C^{14}-chrysanthemumic Acid.—Campbell & Harper (1945) developed an improved method for the synthesis of the unlabeled acid starting with ethyl glycinate hydrochloride. They isolated and adequately described the acid and the intermediates ethyl diazoacetate and ethyl-*dl-cis,trans*-chrysanthemumate. Their synthesis has been modified to eliminate the isolation of these intermediates, for reasons already stated above, and to include a modification of the improved procedure described by LaForge *et al.* (1952) for ethyl diazoacetate.

The *ethyl diazo-2-C^{14}-acetate* was prepared batchwise by using two small separatory funnels and the following proportions of reagents: ethyl-2-C^{14}-glycinate hydrochloride 3.54 g. (25.5 mM), sodium nitrite 2.6 g. (37 mM), sodium acetate 30 mg. (0.22 mM), 2,5-dimethyl-2,4-hexadiene[4] as solvent 23 ml. in 4- and 3-ml. portions; water 14 ml., 10 per cent sulfuric acid 2.5 ml. in 0.5-ml. portions. The temperature was controlled by swirling the reaction mixture in a small separatory funnel held in a water bath maintained at 15° C. After each dropwise addition of acid, the hexadiene layer was thoroughly equilibrated, separated, and passed by mild suction through a 5-g. column of anhydrous sodium carbonate. The hexadiene extracts were combined and used later.

The final extracted aqueous layer had radioactive material equivalent to 43 mg. of ethyl 2-C^{14}-glycinate hydrochloride.

The *ethyl dl-cis, trans-2-C^{14}-chrysanthemumate* was prepared by the dropwise addition of the combined hexadiene extracts of ethyl diazo-2-C^{14}-acetate to a refluxing mixture of 10 ml. of the hexadiene and 300 mg. of copper powder. The yield of nitrogen was 510 ml. (89 per cent), but part of the nitrogen was lost. In a previous run with unlabeled substance the yield of nitrogen was 97 per cent.

In the same apparatus the excess hexadiene with only a trace of radioactivity was distilled at 30–35°/12 mm. from the reaction mixture, and the ester was saponified by boiling for 2 hours with 2 g. of sodium hydroxide dissolved in 3 ml. of water and 15 ml. of ethanol. The acidic products (3.16 g.) were isolated in the usual manner and distilled at 1 mm. pressure. The *dl-cis,trans*-2-C^{14}-chrysanthemumic acid, 2.26 g. (13.3 mM, 49.8 per cent of theory based on the original diluted 2-C^{14}-glycine), boiled at 107–109° C. and readily crystallized when cooled. It had a specific radioactivity of 7,719 c.p.m. per milligram.

The nonacidic products and the ether-extracted, acidified aqueous solution contained, respectively, radioactivity equivalent to about 5 mg. and 292 mg. of ethyl 2-C^{14}-glycinate hydrochloride.

The combined forerun and still residue (0.8 g.) had radioactivity equivalent to 733 mg. of the acid, and has been set aside for separation by a more appropriate method.

dl-cis,trans-C^{14}-Allethrin.—Schechter *et al.* (1949) prepared *dl*-allethrolone and then by acylation with *dl-cis,trans*-chrysanthemumic acid chloride (LaForge & Barthel 1947) prepared unlabeled *dl-cis, trans*-allethrin. Their procedure was modified to take advantage of transfer in a small, closed vacuum system provided with a removable drying tube and a distilling tube with one permanently attached dry-ice trap having a ground joint for connecting auxiliary traps.

With a bulb pipette 100 mg. (0.59 mM)

[4] Kindly furnished by H. A. Jones, U. S. Industrial Chemicals Co., Baltimore, Md., and recrystallized before use.

of the *dl-cis,trans*-2-C^{14}-chrysanthemumic acid was transferred with 2 ml. of dry Skellysolve B in small portions to the distilling tube, and the solvent was transferred at 12 mm. pressure to the second trap, which was then replaced with a stopper. The residue was allowed to react under anhydrous conditions overnight in a warm hood with 100 mg. (0.89 mM) of purified thionyl chloride dissolved in 1.5 ml. of dry Skellysolve B. The solvent and excess thionyl chloride were transferred at 12 mm. pressure to the second trap, and then the acid chloride was transferred to the first trap at 1 mm. pressure in a water bath at 95–100° C.

The acid chloride, dissolved in 0.5 ml. of dry benzene, was allowed to react in the trap overnight (time seems important) under anhydrous conditions with 100 mg. (0.72 mM) of *dl*-allethrolone (purified by distillation after regeneration from the recrystallized semicarbazone) and 75 mg. (0.95 mM) of dry pyridine dissolved in 1 ml. of dry benzene. The reaction mixture was transferred with 1 ml. of dilute hydrochloric acid and 1.5 ml. of Skellysolve B in small portions to a small, tared, glass-stoppered centrifuge tube, where it was thoroughly washed with water with the aid of centrifugation and a bulb pipette. The solvent was removed from the reaction mixture in a closed system, first at 12 mm. by heating the tube in an ice-salt bath, and finally at 1 mm. in a water bath at 35–40° C. The almost colorless oily residue of crude *dl-cis,trans*-C^{14}-allethrin weighed 167.4 mg. (0.55 mM), 93 per cent based on the acid.

All the combined solvent distillates, the still residue, and the water wash had radioactivity equivalent to about 8 mg. of the labeled acid.

Chromatographic purification of dl-cis, trans-C^{14}*-allethrin.*—The 167.4 mg. of crude *dl-cis,trans*-C^{14}-allethrin was partitioned chromatographically[3] between *n*-hexane and nitromethane on a column of silicic acid (Mallinckrodt, chromatographic grade). Unlike the original procedure, collection of the mobile phase was started with the introduction of the sample and continued under air pressure at 3–4 p.s.i. The eluate was collected in 5 ml. portions near the expected break between fractions. The solvent was removed under reduced pressure from the separate aliquots of eluate. These aliquots were appropriately combined to yield the following fractions, which were tested for toxicity to house flies:

A—56–95 ml., acid or anhydride, 1.3 mg., nontoxic, specific radioactivity 7583 c/m/mg.

B—101–125 ml., acid or anhydride, 3.1 mg., nontoxic, specific radioactivity 2795 c/m/mg.

C—131–250 ml., *dl-cis,trans*-C^{14}-allethrin, 132.9 mg. (0.55 mM) 74.5 per cent based on acid, LD_{50} 0.2 microgram per fly, specific radioactivity 4278 c/m/mg.

D—261–320 ml., unknown, 0.5 mg., slightly toxic, specific radioactivity 4638 c/m/mg.

E—341–460 ml., unknown, 0.3 mg., slightly toxic, specific radioactivity 7074 c/m/mg.

F—bottom one-third of sectioned column extracted with acetone, unknown, 2.4 mg., nontoxic, specific radioactivity 1830 c/m/mg.

G—middle one-third of column, unknown, 2.6 mg., nontoxic, specific radioactivity 551 c/m/mg.

H—top one-third of column, excess *dl*-allethrolone plus unknown, 6.9 mg., nontoxic, specific radioactivity 1462 c/m/mg.

Only 152.9 mg. (91.4 per cent) was recovered from the column. Thus it appears that some by-products of allethrin synthesis are not readily removed from silicic acid by acetone. Higher recoveries were made by Harris from the sample of purified allethrin.

Summary.—Radioactive allethrin has been synthesized to facilitate a study of the metabolic fate of toxic esters of chrysanthemumic acid after their application to house flies and cockroaches. After having been purified by chromatography, the radioactive allethrin appeared to be approximately 98 per cent pure.

LITERATURE CITED

Blatt, A. H., Editor. 1943. Organic syntheses. Coll. Vol. 2, p. 310. John Wiley and Sons, New York.

Block, Richard J., Raymond LeStrange, and Gunter Zweig. 1952. Paper chromatography. Academic Press, New York.

Campbell, I. G. M., and Stanley H. Harper. 1945. Experiments on the synthesis of the pyrethrins. Part I. Synthesis of chrysanthemum monocarboxylic acid. Jour. Chem. Soc.: 283–6.

Hogsett, J. N., H. W. Kacy, and J. R. Johnson. 1953. Analysis of commercial allethrin. Determination of allethrin content by reaction with ethylenediamine. Anal. Chem. **25**: 1207–11.
LaForge, F. B., and W. F. Barthel. 1947. Constituents of pyrethrum flowers. XX. The partial synthesis of pyrthrins and cinerins and their relative toxicities. Jour. Org. Chem. **12**: 199–202.
LaForge, F. B., W. A. Gersdorff, Nathan Green, and M. S. Schechter. 1952. Allethrin-type esters of cyclopropanecarboxylic acids and their relative toxicities to houseflies. Jour. Org. Chem. **17**: 381–9.
Oiwa, T., Y. Inone, J. Ueda, and M. Ohno. 1952a. Polarographic determination of allethrin. I. Studies on determination of pyrethroids. Botyu-Kagaku. **17**: 106–22.
Oiwa, T., Y. Yamada, and M. Ohno. 1952b. Bul. Inst. Chem. Res. Kyoto Univ. **29**: 38.
Schechter, Milton S., Nathan Green, and F. B. LaForge. 1949. Constituents of pyrethrum flowers. XXIII. Cinerolone and the synthesis of related cyclopentenolones. Jour. Amer. Chem. Soc. **71**: 3165–73.

Seasonal Incidence of Fleas on the California Ground Squirrel in Orange County, California[1]

RAYMOND E. RYCKMAN, CHESTER C. LINDT, CHARLES T. AMES, and ROBERT D. LEE,[2]
School of Tropical and Preventive Medicine, Loma Linda, California

During 1951 and 1952 field studies were conducted at Dana Point, Orange County, California, for the purpose of controlling fleas on the California ground squirrel, *Citellus beecheyi beecheyi* (Richardson), under field conditions by insecticides (Ryckman *et al.* 1953). Throughout the investigation several untreated control populations were studied for comparison with the squirrel populations exposed to chlorinated hydrocarbons. Data presented in this paper are concerned only with the seasonal incidence of fleas on untreated animals from the control populations. The data presented were collected from 258 ground squirrels over a period of 17 consecutive months, August, 1951, through December, 1952.

The seasonal population of *Diamanus montanus* (Baker 1895) and *Hoplopsyllus anomalus* (Baker 1904) in general parallels the data obtained by Stewart & Evans (1941) and Holdenreid *et al.* (1951) in their studies in northern California, Alameda County; however, *Echidnophaga gallinacea* (Westwood 1875) is a notable exception. Holdenreid *et al.* (1951) studied ground squirrels and their ectoparasites from 1940–1945 in Alameda County, California, and did not report *E. gallinacea* from *Citellus beecheyi*. Linsdale (1946 p. 298–300) reported that *E. gallinacea* constituted 3.3 per cent of the fleas collected from ground squirrels during a 1-year period in Monterrey County, California. The authors have found *E. gallinacea* to be the numerically dominant flea species in Orange County, California, during the months August through December. See accompanying figures 1, 2, and 3.[3]

The index of *Echidnophaga gallinacea* began rising sharply in July and reached a peak index of 66 fleas per squirrel in October, 1952. A sharp decline in the index for this species occurred late in October and may be correlated with an increase in rainfall and an abrupt decline in the mean temperature. From the data presented in figure 1, it is apparent that *E. gallinacea* is most abundant during the hot, dry season, July through November. An increase in rainfall and a drop in the mean monthly temperature is definitely correlated with an abrupt decline in the population of *E. gallinacea;* additional studies conducted in San Bernardino County, California, during 1952 and 1953 have also indicated that the index of *E. gallinacea* is adversely affected by cool weather associated with fall or early winter rains.

All animals and fleas in this study were collected within 2 miles of the Pacific Ocean. The climate in this area is tempered greatly in comparison with the inland valleys of southern California; the mean summer temperature is cooler and the evaporation rate less near the ocean. Projecting the concept further that the

[1] This investigation was made possible by a contract (DA-49-007-MD-185) from the Research and Development Board, Office of the Surgeon General, Department of the Army.
[2] The authors acknowledge with appreciation the assistance of Dean Spencer, Barbara A. Deem, Ken Y. Arakawa, Karl C. Fischer, and Christian P. Christianson.
[3] Responsibilities for part of the cost of reproducing these figures has been assumed by the authors.

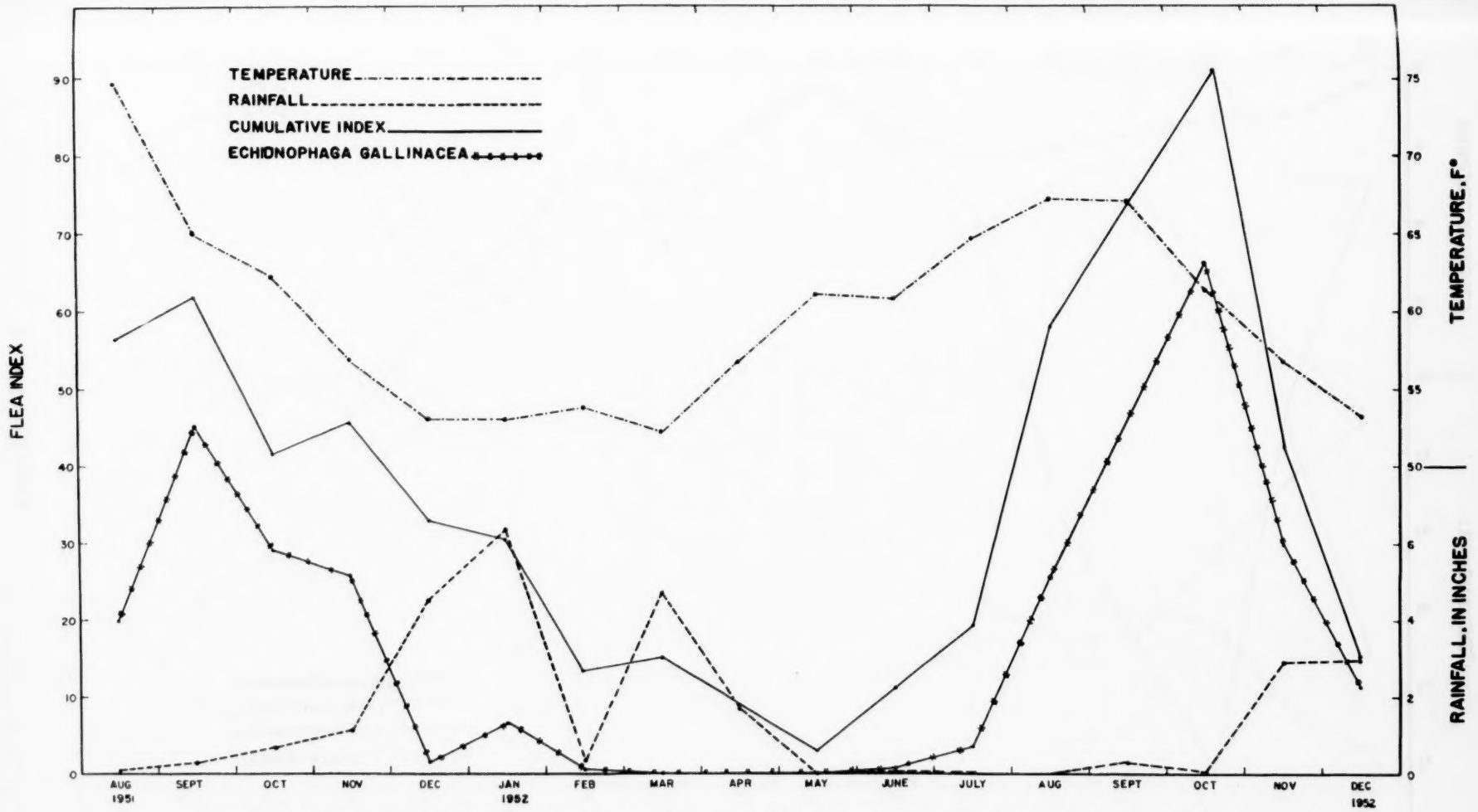


FIG. 1.—This graph indicates a correlation between the seasonal incidence of *Echidnophaga gallinacea* and environmental conditions relative to temperature and humidity. A rise in the mean temperature and a reduction in rainfall resulted in a sharp rise in the *E. gallinacea* index.

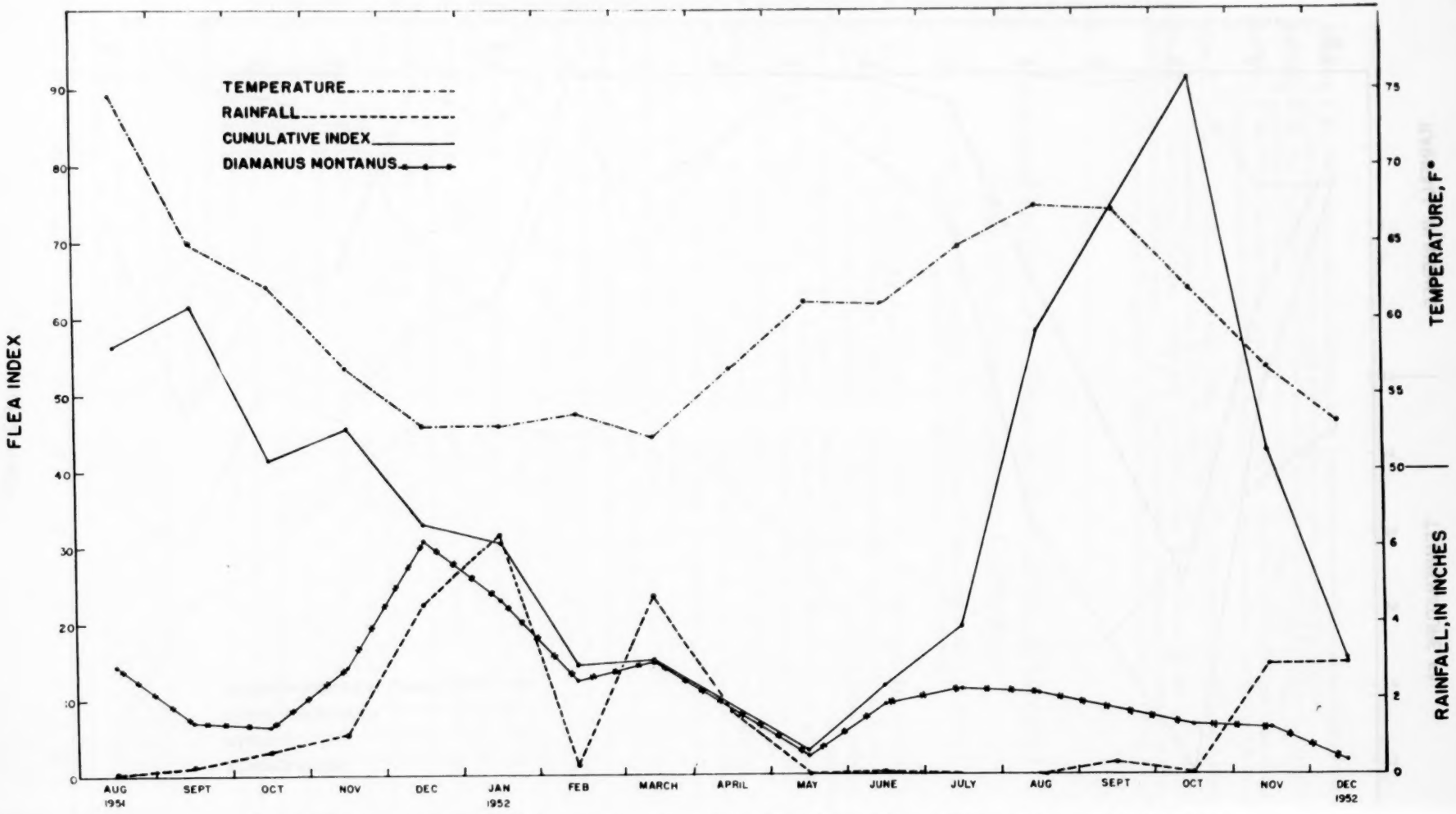


FIG. 2.—*Diamanus montanus* reached a seasonal maximum during November to February. However, the seasonal incidence of *D. montanus* did not fluctuate as greatly as *Echidnophaga gallinacea* or *Hoplopsyllus anomalus*.

D. montanus did not fluctuate as greatly as *Echidnophaga gallinacea* or *Hoplopsyllus anomalus*.

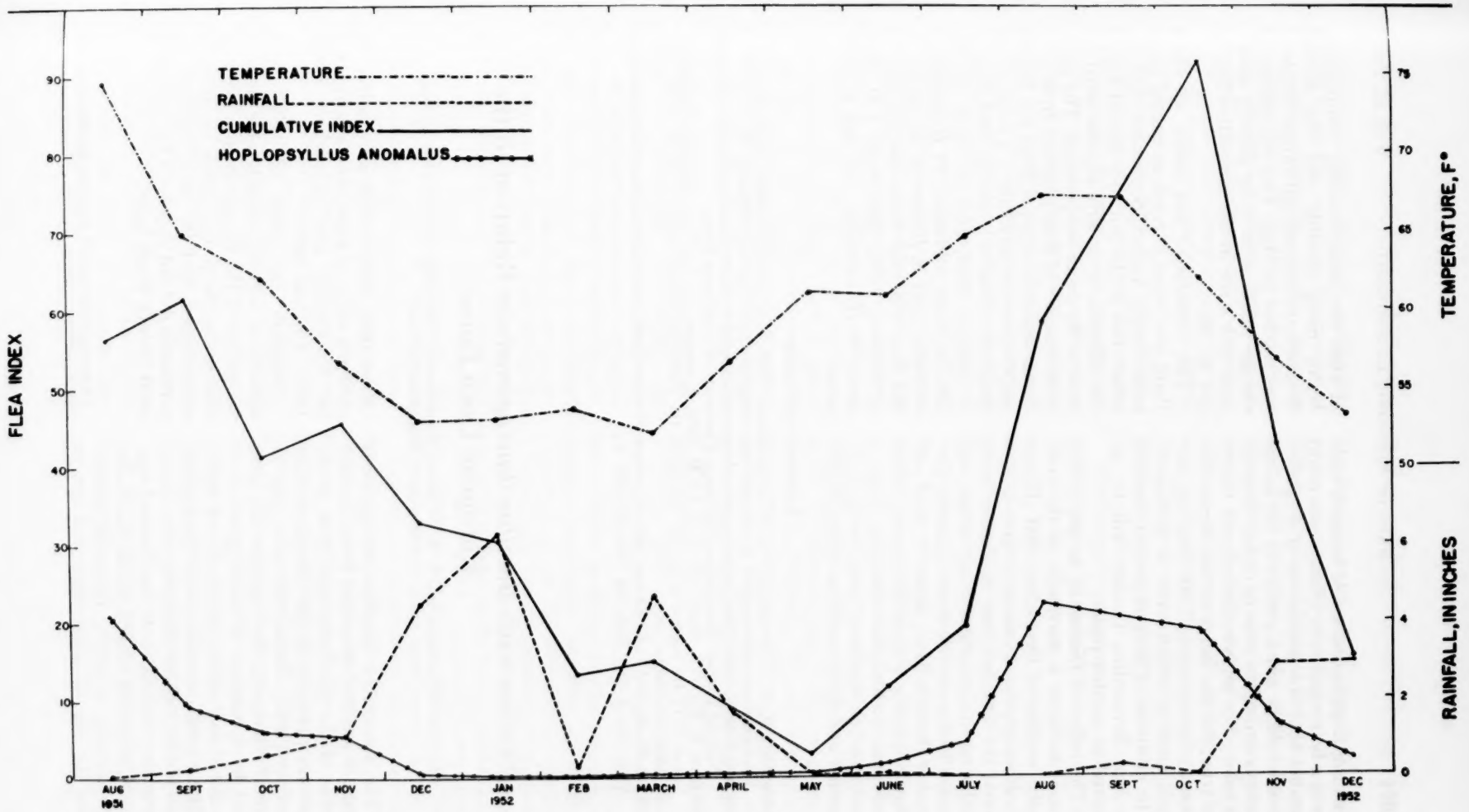


FIG. 3.—*Hoplopsyllus anomalus* reached a seasonal high from August to October; the seasonal curve for this species is quite similar to that of *Echidnophaga gallinacea* with the exception that *E. gallinacea* reached a much higher index.

index of *E. gallinacea* would be much higher in a hotter and drier climate, one might predict that the population of *E. gallinacea* would be much greater in the inland valleys during the months of July through October. The authors have found this to be true; the flea index in San Bernardino County has exceeded 1,000 fleas per animal, most of which were *E. gallinacea*. The incidence of fleas on ground squirrels in San Bernardino County will be reported in another paper.

The index of *Diamanus montanus* was found to be at a maximum in the cool, moist weather of December, 1951 (Figure 2). *Hoplopsyllus anomalus* in general followed the *Echidnophaga gallinacea* curve with a maximum index during the hot, dry season and a very low index during December through May, figure 3. April and May constitute a transition period when ecological factors are changing from a cool, moist environment to an increasingly warmer and drier condition. After March of 1952 the mean monthly temperature began rising steadily and the rainfall dropped continuously until a near zero level was reached in May. This environmental change would seem to be directly associated with a rise in the cumulative flea index in May.

The cumulative flea index at Dana Point was found to reach an annual maximum during August, September, and October; this is the hot, dry period before the fall rains occur with an associated decline in the mean temperature. The maximum number of fleas recorded from individual squirrels at Dana Point for August and October are as follows: A total of 208 fleas were collected from a squirrel trapped in August, 1952, and consisted of 155 *Echidnophaga gallinacea*, 37 *Hoplopsyllus anomalus*, and 16 *Diamanus montanus*. Of 223 fleas collected from another squirrel in October, 1952, there were 5 *D. montanus*, 10 *H. anomalus*, and 208 *E. gallinacea*.

LITERATURE CITED

Holdenreid, R., F. C. Evans, and D. S. Longanecker. 1951. Host-parasite-disease relationships in a mammalian community in the central coast range of California. Ecol. Monogr. **21**: 1–18.

Linsdale, Jean M. 1946. The California ground squirrel, a record of observations made on the Hastings Natural History Reservation. Berkeley: University of California Press.

Ryckman, R. E., C. T. Ames, and C. C. Lindt. 1953. A comparison of Aldrin, Dieldrin, Heptachlor, and DDT for control of plague vectors on the California ground squirrel. JOUR. ECON. ENT. **46**(4): 598–601.

Stewart, M. A., and F. C. Evans. 1941. A comparative study of rodent and burrow flea populations. Proc. Soc. Exper. Biol. and Med. **47**: 140–2.

Studies with *Bacillus thuringiensis* in Relation to the European Corn Borer[1]

ELLICOTT MCCONNELL and L. K. CUTKOMP, *Department of Entomology and Economic Zoology, University of Minnesota, St. Paul*

The bacterium *Bacillus thuringiensis* Berliner was first described from diseased larvae of the Mediterranean flour moth, *Ephestia kühniella*, by the German worker Berliner (1915). Under this name and its several synonyms, the organism has been tried by a number of investigators as a means of controlling various insect pests.

Husz (1927) demonstrated the marked susceptibility of the European corn borer, *Pyrausta nubilalis*, to the bacillus and suggested its use for control of this insect. He subsequently reported favorable results from the use of spore dusts and sprays (Husz 1929, 1930) which were substantiated in a series of experiments carried out by Metalnikov and co-workers (1929, 1930) (Chorine 1930).

Although the work of this period seemed to indicate considerable promise for control of the European corn borer by this means, the projects were inexplicably discontinued, and the next reported experiments did not appear in the literature until twenty years later.

[1] Paper No. 3171, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

Steinhaus (1951) reported considerable success using the organism for control of the alfalfa caterpillar, *Colias philodice eurytheme* Bdvl. This larva presents a slightly different problem than does the corn borer, as it feeds only on the exterior of the plant, and therefore may be exposed to treatment for its entire larval existence.

Except for the work of Mattes (1927), most of the research involving this organism has been concerned with its preparation for use in the field and its application to crops. It is the purpose of this paper to present the results of an investigation of some of the relationships existing between the corn borer and the bacterium, *Bacillus thuringiensis*. The problem was attacked by setting up experiments to establish the following points: (1) the number of spores necessary to produce a lethal effect on the larvae; (2) the pathogenicity of a related bacillus for the corn borer; (3) effect of temperature on the speed of infection; (4) absence of a repellent effect of spore suspensions for larvae; (5) relationship of larval age to susceptibility; (6) response of larvae to treatment in field infestations; (7) course of infection within the larvae.

TAXONOMIC POSITION OF *Bacillus Thuringiensis* BERLINER.—According to Smith, Gordon, and Clark (1946), the strain of *Bacillus thuringiensis* they studied corresponds to *Bacillus cereus* Frankland and Frankland. It has been found though, that most strains of *B. cereus* are not pathogenic for insects, while the pathogenicity of *B. thuringiensis* seems to be a persistent characteristic. Steinhaus (1951) believes, for this reason and because of the possible economic significance involved, that the name *B. thuringiensis* should be retained and kept separate from *B. cereus*. This would allow for continuity in entomological literature where the specific name *thuringiensis* has been used since proposed by Berliner in 1915.

METHODS AND MATERIALS.—The spore material used in the following experiment was grown on Difco nutrient agar placed in a shallow Ovenex baking pan (11.5″ × 17.5″).[2] Povitsky bottles, used by Steinhaus (1951), were not available. In addition it was believed that use of the pan would facilitate harvesting of the spore material from the surface of the agar. The tray was fitted with a loose fitting cover by a local tinsmith which allowed the tray to be manipulated as a large petri dish. Five hundred milliliters of Difco nutrient agar filled the tray to the desired level. After allowing the agar to cool, a suspension of the bacteria was sprayed from a dilution bottle upon the surface of the agar with a sterile Windex spray apparatus. The tray was then inverted and incubated at room temperature (about 25° C.) for 5 to 7 days.

Microscopic examination indicated sporulation to be complete by the end of the third day. However, it was found that several days additional incubation time allowed sufficient desiccation of the agar to facilitate removal of the spore material. The spores were harvested by scraping the surface of the agar with a smooth glass rod. After removal, the spores were suspended in approximately 100 milliliters of distilled water and washed once by centrifugation. The centrifugate was then placed in petri dishes and allowed to dry at 30° C. Evaporation of the water was complete in 24 hours. The dry deposit of spores was scraped into a mortar and ground to a fine powder. Each lot of spores was then placed in clean shell vials, corked, and stored in the dark at room temperature.

The dry spore material was resuspended in distilled water for use in either the field or laboratory. A stainless steel Waring Blendor was employed in this process to assure a maximum breaking up of the clumps of spores. The blendor was run for 1 minute for the preparation of suspensions used in the laboratory experiments, and for 2 minutes in the case of the heavier suspensions which were used for preparing the sprays used in the field work. No spreading or sticking agents were used.

Egg masses for use in the laboratory experiments were procured from the Corn Borer Project (for production of egg masses see Patch & Peirce 1933) and placed in a 1-gallon battery jar which was covered with waxed paper.[3] No food material was added. At the end of 24 hours, the larvae which had hatched were removed to the experimental vials with a camel's-hair brush. The egg masses used in the field experiments were taken di-

[2] The cultures of *B. thuringiensis* employed in this work were obtained through the courtesy of Dr. E. A. Steinhaus, University of California.

[3] The authors are grateful to Dr. F. G. Holdaway for his assistance in the procurement of egg masses.

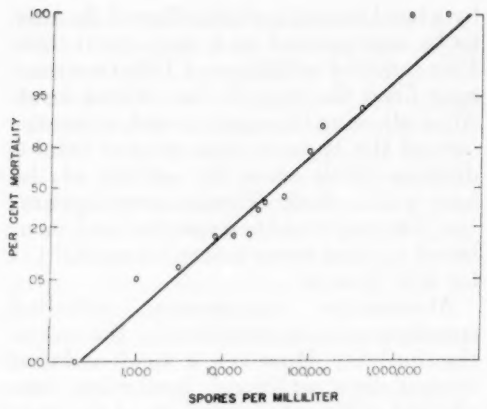


FIG. 1.—Relation of the mortality of first instar corn borer larvae to the concentration of spores per milliliter applied to food material (data from Table 1. 33,000,000 concentration level omitted).

rectly from the storage boards and placed in the whorls of the corn plants.

Shell vials of 6-dram capacity were used for exposing the larvae to food which had been treated with various dilutions of spore suspensions. Ten first-instar larvae were placed on previously treated food material in each vial which was then stoppered with wax paper and elastic bands. The use of the wax paper eliminated the possibility of larvae boring into corks and becoming lost. In addition, it was found that many larvae were killed or injured during the removal of cork or rubber stoppers. This was particularly liable to occur in the case of infected larvae which displayed a marked tendency to leave the food supply and wander about the sides of the vials.

The inner layers of the corn husk were found to be an ideal food source for this work for the following reasons: (1) The material is succulent and highly acceptable to the larvae; (2) the outer layers of the husk act as protection from contamination in the field; (3) as there is little variation in texture throughout the growth period of the corn ear, a supply is constantly available for an extended period of time during the growing season.

The spore suspensions were applied by dipping sections of corn husk directly into the desired dilution. The excess liquid was shaken off and the sections allowed to drain for approximately 5 minutes before placing in the shell vials. Observation under a binocular microscope showed that a thin layer of the suspension was retained, apparently by minute irregularities on the surface of the husk.

Each dilution of spore suspension was counted in triplicate by standard plate count technique.

At an incubation temperature of 30° C., dead larvae began to appear in the experimental vials approximately 24 hours following ingestion of spores. Due to the rapid progress of the infection within the insects, it was found that a period of 36 hours from the time of exposure allowed ample time for all infected larvae to succumb when incubated at the above temperature. At the end of this period, the vials were opened and the dead larvae counted. A larva was considered dead if it did not respond to prodding with a camel's-hair brush. Those larvae which were critically injured by handling at the time they were placed in the vials would shrivel up or disintegrate during the incubation period. Therefore, any larvae unaccounted for at the end of the incubation period were assumed to have died as a result of mistreatment and were deducted from the experimental total.

LABORATORY STUDIES.—*Spore Concentration as Related to Larval Mortality.*—An attempt was made to determine the dosage-mortality relationship for first instar corn borer larvae.

Three 10-milligram lots of spores were each suspended in 100 milliliters of sterile distilled water and mixed in the Waring Blendor for 1 minute. Each suspension was then diluted out five times, the first two suspensions in tenfold dilutions, and the last suspension by halves. Forty larvae were tested at each of the dilutions in the first lot, and 50 larvae at each dilution in the second two series. A set of control vials containing food material treated with sterile distilled water was run with each of the three series of dilutions. All the larvae were maintained at 30° C. for the duration of the experiment. The dead larvae were counted after 48 hours with the results shown in table 1. When plotted on a probit scale (Fig. 1), the results indicate the LD 50 for first instar, unfed corn borer larvae to be approximately 50,000 spores per milliliter.

Test to Determine Pathogenicity of a Closely Related Bacillus.—Spore material was prepared from a culture of *Bacillus cereus* following the procedure previously

Table 1.—Combined results of three experiments to determine the mortality of first-instar corn borer larvae after feeding for 48 hours on sections of corn leaf treated with spores of *Bacillus thuringiensis* at different concentrations.

Spores per Ml.	No. of Larvae	No. Dead	Percentage Mortality[1]
200	48	2	0.0
1,500	39	2	2.5
3,000	47	7	4.7
8,000	49	9	14.9
13,000	49	9	14.9
20,000	34	6	15.4
25,000	38	13	31.4
30,000	45	20	38.0
50,000	48	21	41.4
100,000	45	35	76.8
140,000	34	31	91.0
400,000	49	47	95.4
1,500,000	40	40	100.0
4,000,000	50	50	100.0
33,000,000	38	37	97.2
Control No. 1	37	1	2.7
Control No. 2	48	5	10.2
Control No. 3	49	2	4.1

[1] Corrected according to Abbott's formula.

described for the production of spores from *B. thuringiensis*. This organism was chosen because it is close in taxonomic position to *B. thuringiensis* (Smith *et al.* 1946).

Two dilutions were tested with the results shown in table 2. It can be stated, therefore, that first-instar corn borer larvae suffer no appreciable mortality when exposed to spores from a typical strain of *B. cereus* at a concentration exceeding the lethal level for spores of *B. thuringiensis*.

Temperature-Mortality Relationship.—Three sets of spore dilutions were used to determine the relationship between temperature and the rapidity of the infectious process. If was particularly desired to determine if the corn borer larvae would show an increased resistance to infection at the high temperature of 35° C. However, a positive relationship was indicated between temperature and the rapidity of infection for the range of temperatures tested (Table 3). It should be emphasized that the temperature-mortality relationship is concerned only with the rapidity of infection. All the larvae were exposed to spore concentrations exceeding the minimum lethal dose, and the majority eventually succumbed.

Table 2.—Mortality of first instar corn borer larvae after exposure for 48 hours on sections of corn leaf treated with spores of *Bacillus cereus* at two concentrations.

Spores per Ml.	No. of Larvae	No. Dead	Percentage Mortality
900,000	49	2	4.1
4,000,000	47	2	4.3
Control	49	1	2.0

Table 3.—Rate of infection at different temperatures as indicated by mortality of first-instar corn borer larvae after feeding for 36 hours on sections of corn leaf treated with spores of *Bacillus thuringiensis*.[1]

Spores per Ml.	Temperature (Degrees Cent.)	No. of Larvae	Percentage Mortality[2]
450,000	20	50	34.0
450,000	25	48	39.6
450,000	30	45	75.4
450,000	35	48	97.8
600,000	20	35	35.7
600,000	25	33	72.7
600,000	35	38	100.0
5,000,000	20	37	64.0
5,000,000	25	39	87.0
5,000,000	30	38	100.0
5,000,000	35	40	100.0

[1] Controls not shown.
[2] Corrected according to Abbott's formula.

Repellency.—Observations made during the course of the previous experiments revealed that only slight feeding damage occurred in those vials which subsequently exhibited high mortality. Although it is reported that loss of appetite occurs within several hours after ingestion of spores (Steinhaus 1951), an attempt was made to determine if an additional repellent effect was being manifested. The possibility existed, that material present in the spore suspensions, other than the living spores, could account for any repellent effect which might be demonstrated. To check this possibility, three groups of first-instar larvae were exposed to food material treated as indicated in table 4. Heavy feeding was observed in each treatment suggesting that the presence of living spores is necessary to produce a change in feeding intensity.

In the second phase of this experiment, three groups of 50 larvae each were confined to vials each containing two similar pieces of corn husk, one piece of which had

Table 4.—The amount of feeding and mortality of first-instar larvae of the European corn borer exposed to non-viable spores on sections of corn leaves for 36-hour periods.

Treatment	Spores per Ml.	No. of Larvae	Percentage Mortality	Feeding Damage
Autoclaved 5 min. at 15 lbs. pressure	450,000	50	0	Heavy
Boiled for 10 minutes	400,000	50	6	Heavy
Nutrient agar 0.15 per cent	—	50	0	Heavy

been dipped in spore suspension, the other in distilled water. The first group of larvae were placed on the sides of the vials, the second group on the treated food, and the third group on the untreated material. All vials were read at 12 and 24 hours, and the positions of the larvae noted (Table 5). No marked tendency for the larvae to avoid the treated food material is indicated. Although this experiment does not eliminate the possibility of a repellent effect, the results are more likely an indication of the restlessenss of those larvae which had ingested spores while wandering over the surface of the treated corn husk.

Relationship of Larval Age to Susceptibility.—Preliminary tests indicate that susceptibility to infection decreases with the age of the larvae. They were carried out as follows:

(1) Five 4th-instar larvae were exposed to each of the following concentrations of spore suspensions: 200, 3,000, 30,000, 400,000, and 4 million spores per milliliter. One larvae, only at the highest concentration, succumbed with typical symptoms.

(2) Ten 4th-instar larvae were exposed to a concentration of 300,000 spores per milliliter, and 10 others exposed to 3 million spores per milliliter Two of the larvae exposed to the higher concentration died.

These experiments, although not conclusive, suggest that a direct relationship exists between the size or age of the larvae and the number of spores which must be ingested to produce a lethal effect.

Histopathology.—Examination of stained sections of infected fifth-instar larvae indicated a rapidly terminating infection similar to that reported by Mattes (1927) for *Ephestia kühniella* Zeller. Fifteen hours following the ingestion of viable spores only the sclerotized portions and the cuticular epithelium remain essentially intact.

FIELD EXPERIMENTS.—Two field experiments were carried out in the summer of 1951 to determine the effectiveness of spore suspensions when applied under field conditions. The very light natural infestation of the European corn borer in the experimental area made it necessary to restrict the work to hand-infested plants.

Upon reaching a predetermined stage of maturity, the plants in the experimental plots were sprayed with an aqueous suspension of spores. A new 3-gallon hand sprayer was used for this purpose. Spraying was carried out in the early morning to avoid interference from wind currents. Each plant was sprayed thoroughly, with particular attention being given to the region of the whorl of the corn plant. In the afternoon of the same day, two egg masses were placed in the whorl of each treated plant. The following day a third egg mass was added. The control plants were infested at the same time and in the same manner as the treated plants.

The measurement used for a criterion of growth consisted of the height of the growing point above ground level (distance from the base of the plant to the base of the tassel bud) as determined by dissection, divided by the extended height (distance from the base of the plant to the tip of the longest leaf extended) of the plant. This may be designated as the tassel-base ratio (Fig. 2). For example, a tassel-base ratio of 0.5 indicates the plant has reached a stage of growth in which 3 to 4 inches of the tassel are visible in the whorl.

Table 5.—Results of experiments to determine whether the behavior of the first-instar larvae of the European corn borer was affected as a result of their exposure to different surfaces.[1]

Disposition of Larvae	Exposure Time in Hours	Per Cent on		
		Treated Food	Untreated Food	Side of Vials
On sides of vials	12	26.0	50.0	24.0
	24	22.9	47.9	29.2
On surface of treated food[2]	12	27.8	41.8	30.6
	24	27.0	40.5	32.4
On surface of untreated food	12	19.6	37.0	43.5
	24	11.6	37.2	51.2

[1] Fifty larvae were placed on each type of surface.
[2] Placed on corn leaves treated with viable spores (5,500,000 spores per ml.).

This measurement for determining a stage of growth of the corn plant was a modification of that used and described by Luckmann & Decker (1952), differing from their "tassel-ratio" in that the base of the tassel was used for the point of measurement, while they measured the tip of the tassel bud.

Field Experiment No. 1.—A plot of borer susceptible corn (A334 × 442)[4] was divided into three replicates. Each replicate was then subdivided into several sections. Spray was applied to one section from each replicate when dissection of several arbitrarily selected plants indicated the average tassel-base ratio for the plot to be approximately 0.5. For this application 1.367 grams of spore material were suspended in 20 liters of distilled water. This yielded a final suspension with a concentration of 12 million spores per milliliter.

Counts for mortality of the first-instar larvae were made 10 days following application of the spray. This included dissection of five plants from each treated section, and five plants from an untreated section in each replicate, or a total of 15 from each section. During this dissection, the observations made indicated that the larvae were concentrated almost exclusively in the florets of tassels. An average of 20.5 larvae were found in the treated plants as compared with an average of 31 in the untreated, a significant difference at the 1 per cent level. A second count was made in a similar manner 24 days after application of the spray but there was no significant difference in mortality between the treated and untreated plots at the end of this period.

Field Experiment No. 2.—In the second field experiment, 30 tolerant plants, Minnesota hybrid 408, were sprayed when the tassel-base ratio reached 0.25. At this time the plants were approximately 30 inches high unextended. Egg masses were applied to the plants as before, three to each of the treated, and three to each of 30 untreated plants to act as controls. The spray contained 0.15 gram of spore material suspended in three liters of water, yielding a final concentration of 6 million spores per milliliter. At the end of 2 weeks, 20 test and 20 check plants were dissected. The treated plants had significantly fewer larvae than the control plants, averaging 0.9 larva as compared with 5.1 in the untreated plants. A number of the remaining plants were destroyed before a final count could be made at harvest time.

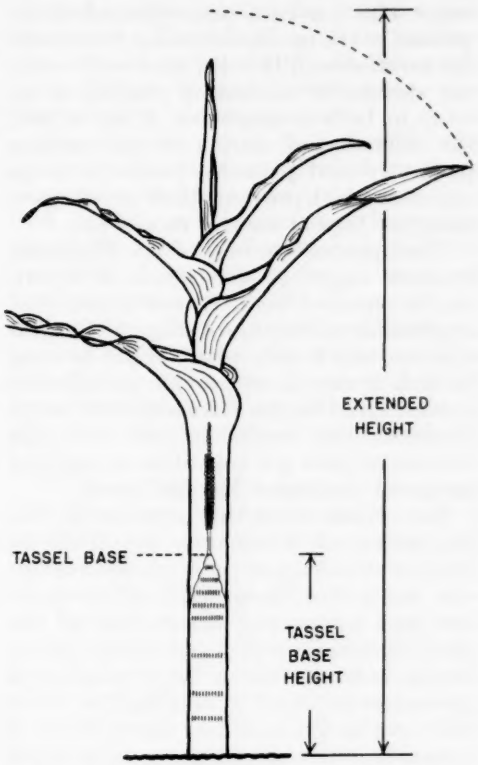


FIG. 2.—Sagittal section of corn plant showing certain characteristics used in determining the stage of growth.

DISCUSSION.—*Bacillus thuringiensis* is of interest as a biological control agent for several reasons. It particularly recommends itself for its ability to grow readily on artificial medium without loss of virulence. This is in sharp contrast with *Bacillus popilliae* Dutky, successfully used for control of the Japanese beetle, and the various viruses. These, in common with predatory and parasitic insects, rely for their reproduction on the availability of fresh host tissue. This causes the accumulation of an effective amount of material to be at best a tedious and exacting procedure. In addition, as a sporeforming bacterium, this organism can be kept available for considerable periods of time with no additional expenditure of time or effort. This is true for all members of the genus *Bacillus*, and for many of the vi-

[4] Rating of susceptibility determined by Dept. of Agronomy.

ruses. This is not the case with such an organism as the non-sporeformer *Coccobacillus acridiorum* d'Herelle, used with varying success in combating plagues of locusts in both hemispheres. It is, in fact, the difficulty of storing or maintaining predatory and parasitic insects in large numbers which prevents their use as emergency or topical control measures.

The apparent success of the Eurpoean workers suggested the series of experiments reported here. It was hoped that application of the spore stage of *Bacillus thuringiensis* to corn plants could be done in such a way as to provide an effective control agent for the European corn borer. However, the results indicate that this bacterium does not constitute a practical means of treatment for this insect.

For utilization of this organism in biological control, it would be ideal if the ingestion of one spore by a susceptible larvae resulted in reproduction of the parasite and subsequent destruction of the host. However, the first and second experiments indicate that a large number of spores are required to establish an infection in a larva, and that the number of spores required to produce a fatal effect increases with the age or size of the larva. This necessitates that a high concentration of spores be maintained on foliage to provide a satisfactory level of mortality among feeding larvae. For those crops which are attacked by externally feeding insects, and which at the time of attack are in a relatively stable stage of growth, this does not present an insurmountable problem. For example, Steinhaus (1951) reported favorable results using spore suspensions of this organism against the alfalfa caterpillar, *Colias philodice eurytheme* Bdvl.

The corn borer presents quite a different problem. In the first place the larvae feed only to a limited extent on the external, exposed leaves, usually in the vicinity of the whorl. As the leaves of the corn plant may grow as much as 3 or 4 inches out from the whorl in 1 day, it is apparent that it will necessitate almost daily application to maintain a lethal concentration of spores on or in the area where the majority of the feeding will occur. Finally, the young larvae tend to bore into the plant or descend deep into the whorl as soon as a suitable point of entrance becomes available, thus escaping exposure to the externally applied spores. For instance, it is apparent from the first field experiment that larvae showed a low mortality rate when hatching occurred after the tassel appeared in the whorl. This is believed to be correlated with the observation that the newly hatched larvae on those plants immediately burrowed into the florets of the tassel without noticeable external feeding.

It is possible that some of the success of the European workers resulted from the use of corn plants in early stages of growth. No direct reference is made to the size of the plants used in any of the experiments reported in the International Corn Borer Investigations (1928, 1929, 1930). However, Chorine (1930) states that a 5-liter aqueous suspension of spores served to spray up to 1,200 plants. It can be inferred from this small volume of spray, that the plants must have been rather small. The restricted amount of shelter offered by plants of this size may have forced the larvae to remain in positions where a greater opportunity existed for contact with the spray material than would have been the case with more mature plants.

There is no specific statement by any of the European workers as to the concentration of the spore suspensions or dusts which were employed in their experiments. Reference is made to the approximate quantity of diluent per petri dish or Roux bottle of bacterial growth, but there is no expression of concentration in terms of the number of spores present. Therefore, it is impossible to make a direct comparison between those investigations and the present work on a basis of the amount of material applied.

Much of the work involving the use of bacteria for the biological control of insect pests has been empirical in nature. This is understandable, as the demand for immediate results often induces workers in the applied sciences to attempt utilization of their knowledge before adequate experimental data are available. This is unfortunate, for it is possible that hasty, ill-advised, usage will lead to early discouragement and the abandonment of that which in fact holds considerable promise. Steinhaus (1949) suggests that this may have been one of the explanations for the lack of success experienced by many workers employing *Cocoobacillus acridi-*

orum d'Her. for the control of locusts.

An outstanding exception to this situation is found in the case of *Bacillus popilliae* Dutky, the causative agent of type A milky disease of the Japanese beetle, *Popillia japonica* Newm. A large number of careful experiments covering every phase of the relationship between the bacillus and the insect were carried out by White and co-workers (1940, 1943), Dutky (1940, 1941, 1942), and Beard (1944, 1945), before the organism was released and recommended for public use. As a result, the intelligent application of this bacterium was immediately accepted as a valuable addition to previously existing control measures.

The present work attempted in a similar way to make a preliminary study of the relationships between *Bacillus thuringiensis* and the European corn borer. It was hoped that an investigation of this type, combining both laboratory and field work, would furnish at least part of the information necessary for the evaluation of this bacterium as a means of controlling the European corn borer.

Summary.—Mortality of first instar corn borer larvae fed on leaves treated with spores of *Bacillus thuringiensis* showed a direct relationship to spore concentration. The LD 50 is at an application rate of approximately 50,000 spores per milliliter. However, older larvae tolerated higher concentrations.

No evidence could be found for the existence of a repellent effect of the spore suspension on first instar larvae.

A positive relationship was found between the rate of infection and the temperature of incubation for a range of temperatures between 20° C. and 35° C. This had an effect on the rate of infection, and in all instances the ingestion of a lethal dose of spores by a susceptible larva resulted in the rapid destruction of all except the sclerotized portions of the insect.

Field experiments indicated that spore concentrations producing heavy larval mortality in the laboratory cannot be relied upon to produce a significant level of control in the field. The principal reason for lack of effective control appeared to be related to the feeding habits of the corn borer larvae in relation to the growth of the corn plant during the period of attempted control. The small larvae often go deep into the whorl of the plant and may avoid exposure to the spores.

Literature Cited

Beard, R. L. 1944. Susceptibility of Japanese beetle larvae to *Bacillus popilliae*. Jour. Econ. Ent. **37**: 702–8.

Beard, R. L. 1945. Studies on the milky disease of Japanese beetle larvae. Conn. Agr. Expt. Sta. Bul. **491**: 505–81.

Berliner, E. 1915a. Ueber die Schlaffaucht der *Ephestia kühniella* und *Bac. thuringiensis* n. sp. Z. Allg. Entomol. **2**: 21–56.

Chorine, V. 1930. On the use of bacteria in the fight against the corn borer. Intern. Corn Borer Invest., Sci. Repts. **3**: 94–8.

Dutky, S. R. 1940. Two new spore-forming bacteria causing milky diseases of Japanese beetle larvae. Jour. Agr. Research **61**: 57–68.

Dutky, S. R. 1941. Susceptibility of certain scarabaeid larvae to infection by type A milky disease. Jour. Econ. Ent. **34**: 215–6.

Dutky, S. R. 1942. Method for the preparation of spore-dust mixtures of type A milky disease of Japanese beetle larvae for field inoculation. U.S.D.A., Ent. & Pl. Quar.: **ET-192**.

Husz, B. 1927. *Bacillus thuringiensis* Berl. a bacterium pathogenic to corn borer larvae. Intern. Corn Borer Invest., Sci. Repts. **1**: 191–3.

Husz, B. 1929. The use of *Bacillus thuringiensis* in the fight against the corn borer. Intern. Corn Borer Invest., Sci. Repts. **2**: 99–110.

Husz, B. 1930. Field experiments on the application of *Bacillus thuringiensis* against the corn borer. Intern. Corn Borer Invest., Sci. Repts. **3**: 91–8.

Luckmann, W. H., and G. C. Decker. 1952. A corn plant maturity index for use in European corn borer ecological and control investigations. Jour. Econ. Ent. **45**: 226–32.

Mattes, O. 1927. Parasitare Krankheiten der Mehlmottenlarven und Versuche uber ihre Verwendbarkeit als biologisches Bekampfungsmittel. Sitzber. Ges. Beforder. ges. Naturw. Warburg. **62**: 381–417.

Metalnikov, S., and V. Chorine. 1929. Experiments on the use of bacteria to destroy the corn borer. Intern. Corn Borer Invest., Sci. Repts. **2**: 54–9.

Metalnikov, S., D. Hergula and D. M. Strail. 1930. Experiments on the application of bacteria against the corn borer. Intern. Corn Borer Invest., Sci. Repts. **3**: 148–51.

Patch, L. H., and Peirce, L. L. 1933. Laboratory production of clusters of European corn borer eggs for use in hand infestation of corn. Jour. Econ. Ent. **26**: 196–204.

Smith, N. R., Gordon, R. E., and Clark, F. E. 1946. Aerobic mesophilic sporeforming bacteria. U.S.D.A. Misc. Publ. **559**.

Steinhaus, E. A. 1949. Principles of insect pathology. McGraw-Hill Book Co., New York, 757 pp.
Steinhaus, E. A. 1951. Possible use of *Bacillus thuringiensis* Berliner as an aid in the biological control of the alfalfa caterpillar. Hilgardia. **20**: 359–81.
White, R. T., and S. R. Dutky. 1940. Effect of the introduction of milky diseases on populations of Japanese beetle larvae. JOUR. ECON. ENT. **33**: 306–9.
White, R. T., and P. J. McCabe. 1943. Colonization of the organism causing milky disease of Japanese beetle larvae. U.S.D.A. Bur. Ent. & Pl. Quar. **E-605.**

Subchronic Toxicity of Four Chlorinated Dimethanonaphthalene Insecticides to Chicks[1]

MARTIN SHERMAN and MORTON M. ROSENBERG,[2] *University of Hawaii, College of Agriculture, Agricultural Experiment Station, Honolulu*

The acute toxicity to New Hampshire chicks of aldrin, dieldrin, and their respective stereoisomers, isodrin and endrin was reported earlier by Sherman & Rosenberg (1953). The present study was undertaken to determine the subchronic toxicity of these insecticides to chicks.

MATERIALS AND METHODS.—The compositions of the recrystallized compounds tested were as follows: aldrin, 99.3 per cent, m.p. 99.0–100.0° C. (with sublimation); isodrin, 97.5 per cent, sublimes at 98° C.; dieldrin, 99.6 per cent, m.p. 164.0–167.0° C.; and endrin, 96 per cent, sublimes with decomposition at 305.0° C.

The insecticides were added to a standard chick starter ration. Two hundred pounds of ration were placed in a mechanical mixer and 1 quart of an acetone solution of the insecticide was sprayed slowly onto the feed with a hand sprayer as it was being mixed. Aldrin and dieldrin were added on a weight basis at the rates of 50, 25, 12.5, and 6.25 p.p.m. while isodrin and endrin were added at the rates of 12, 6, 3, and 1.5 p.p.m. The total mixing time for each ration was 10 minutes. The control ration was sprayed in a similar manner using 1 quart of redistilled acetone.

Six hundred and eighty New Hampshire chicks were randomized by weight into 34 equal lots at 7 days of age. They were assigned by chance into the top four tiers of Oakes electric battery brooders and the 17 duplicate treatments were assigned at random among them. The surviving chicks were transferred at 21 days of age to unheated grower batteries. During this 42-day study, the chicks received treated feed, water and illumination continuously and the data were obtained as follows: feed consumption was recorded during the first 2 weeks of the experiment; body weights were measured weekly; and mortality was recorded upon daily inspection. Efficiency of feed consumption was obtained by dividing the average units of feed consumed during the first 14 days of this study by the average units of gain in body weight.

RESULTS AND DISCUSSION.—The toxicity of dieldrin, endrin, aldrin, and isodrin is summarized in table 1. Endrin and isodrin were appreciably more toxic than their respective isomers, dieldrin and aldrin. Death occurred rapidly in the lots fed endrin and isodrin, the majority succumbing during the first week on the treated diets. Dieldrin and aldrin, on the other hand, caused death 16 to 34 days after the chicks were placed on the treated diets.

The two highest dosages of endrin and isodrin caused the chicks to become highly excitable during the first week. The slightest disturbance produced flightiness, nervous chirping, and convulsions. The lower dosages caused correspondingly less excitability. The chicks fed 50 p.p.m. of dieldrin and aldrin were also nervous whereas those fed lower amounts appeared normal. In general, the symptoms of intoxication were similar to those described by Sherman & Rosenberg (1953). Excitability decreased as the experiment continued.

Arant (1952) observed that 3- to 6-week

[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 328.
[2] Presented at the Pacific Branch Meeting of the Entomological Society of America, Bend, Oregon, June 22–24, 1954.

Table 1.—Effect of four chlorinated dimethanonaphthalene insecticides on mortality and growth of chicks to 7 weeks of age.[1]

Insecticide	Concentration (P.P.M.)	Mean Per Cent Mortality	Mean Weight Gain Survivors at 7 Weeks (Gms.)	
			Males	Females
Dieldrin	50	17.5	681.8	575.9
	25	0	801.0	647.7
	12.5	2.5	807.6	680.1
	6.25	0	831.9	704.0
Untreated	0.0	0	842.9	703.6
		L.S.D. (5%):	50.9	44.6
		(1%):	67.3	58.9
Endrin	12	95	—[2]	461.5
	6	15	714.3	626.9
	3	0	802.8	685.8
	1.5	0	845.6	702.1
Untreated	0.0	0	842.9	703.6
		L.S.D. (5%):	54.8	37.8
		(1%):	73.0	50.2
Aldrin	50	22.5	709.1	611.9
	25	2.5	814.9	679.3
	12.5	0	855.3	688.6
	6.25	0	851.6	691.9
Untreated	0.0	0	842.9	703.6
		L.S.D. (5%):	52.1	43.7
		(1%):	69.0	57.7
Isodrin	12	92.5	—[2]	576.3
	6	0	783.2	595.6
	3	2.5	784.2	673.3
	1.5	0	875.3	702.0
Untreated	0.0	0	842.9	703.6
		L.S.D. (5%):	61.5	46.4
		(1%):	—	61.5

[1] Forty chicks treated in each lot except dieldrin at 25 p.p.m. had 39.
[2] No survivors.

old chicks fed mash containing 25 p.p.m of aldrin died and Eden (1951) found that similarly aged chicks fed 50 p.p.m. of dieldrin died within 90 days. These results appear to be at variance with the data presented in this paper.

At 7 weeks of age, the surviving chicks were sexed and weighed. These data are also summarized in table 1. Significantly, lower weight gains were made by the female survivors of the treatments containing 50 and 25 p.p.m. of dieldrin, 12 and 6 p.p.m. of endrin, 50 p.p.m. of aldrin, and 12 and 6 p.p.m. of isodrin. Among the male survivors, significantly lower weight gains resulted from feeding rations containing 50 p.p.m. dieldrin, 6 p.p.m. endrin, and 50 p.p.m. aldrin.

The data on average feed consumption and efficiency of feed conversion during the first 2 weeks of this study are given in table 2. Only the feed consumption of the lots fed endrin and isodrin at 12 p.p.m. were markedly lower than that of the controls. This was probably due to the high mortality during the first 2 weeks. The extremely poor feed conversion factor obtained on 12 p.p.m. of endrin was due to the marked retardation in growth of the survivors fed this ration.

Table 2.—Effect of insecticides on feed consumption and efficiency of feed conversion.

Insecticide	Concentration (P.P.M.)	Mean Feed Consumption (Gms./Chick):[1]		Efficiency of Feed Conversion to 3 Weeks of Age
		1 Week	2 Weeks	
Dieldrin	50	121.0	174.2	2.18
	25	129.5	188.5	1.99
	12.5	135.1	185.2	2.08
	6.25	139.5	195.1	2.04
Endrin	12	88.9	102.5	4.41
	6	103.3	194.0	2.20
	3	120.9	195.1	1.96
	1.5	128.6	194.1	2.02
Aldrin	50	126.7	184.1	2.16
	25	138.7	199.9	2.06
	12.5	155.3	200.5	2.18
	6.25	131.7	189.9	2.08
Isodrin	12	52.7	137.5	2.38
	6	126.4	185.9	2.32
	3	138.9	185.4	2.20
	1.5	120.1	196.7	1.90
Untreated	—	133.4	191.6	2.01
L.S.D. (5%):		36.7	37.3	1.17
(1%):		50.5	51.4	1.61

[1] Test begun when chicks were 7 days old.

SUMMARY.—Experiments were conducted over a 42-day period to compare the subchronic toxicity to New Hampshire chicks of aldrin, dieldrin, isodrin, and endrin. Seven-day-old chicks were placed on rations containing graded amounts of these insecticides. Whereas aldrin and dieldrin caused approximately 20 per cent mortality when fed at 50 p.p.m., their respective stereoisomers, isodrin and endrin caused over 90 per cent mortality at dosages of 12 p.p.m. Practically no mortality occurred at the lower levels fed in this investigation.

Data pertaining to weight gain, feed consumption and efficiency of feed conversion are also given.

LITERATURE CITED

Arant, F. S. 1952. Toxicity of aldrin to chickens. JOUR. ECON. ENT. **45**(1): 121.
Eden, W. G. 1951. Toxicity of dieldrin to chickens. JOUR. ECON. ENT. **44**(6): 1013.
Sherman, Martin, and M. M. Rosenberg. 1953. Acute toxicity of four chlorinated dimethanonaphthalene insecticides to chicks. JOUR. ECON. ENT. **46**(6): 1067–70.

Life History and Habits of *Tetranychus desertorum* and *bimaculatus* on Cotton

WILLIAM IGLINSKY, JR.[1] and C. F. RAINWATER, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

None of the methods of conducting life-history experiments on spider mites found in the literature seemed to be readily adaptable to *Tetranychus desertorum* Banks and *bimaculatus* Harvey on cotton. Garman (1923a and b), Melvin (1948), Metcalf (1948), and Siegler (1947) described methods used on other species of spider mites. The methods described herein are the result of more than a year's work, during which time many changes and refinements were made.

METHODS.—Cotton seeds were germinated in moist, sterile sand in tin trays 18 by 14 by 3½ inches, in the bottoms of which several small holes were punched. Two to 3 days after the seeds germinated the seedlings were pulled and transferred to wide-mouthed glass jars, 3½ inches deep and 2½ inches in diameter, containing a plant-nutrient solution. The seedlings were then lightly infested with spider mites, and the jars were placed in steel racks with the shelves 12 inches apart. To the bottom of each shelf was fastened a large piece of white paper, which reflected the light from two 20-watt fluorescent bulbs, suspended just below the paper, onto the plants below. This artificial light was essential to maintain the seedlings in good physiological condition in the laboratory, as well as to provide optimum conditions for the cultures of spider mites. When the infestations reached the saturation level and the seedlings were no longer attractive, they were replaced by new ones in fresh nutrient solution. To get the infestation started on the new plants, a few of the discarded plants were placed across their tops in each jar. As the old plants dried, the mites readily transferred to the fresh plants.

For the actual experiments seedling plants about 1 week old were used. Each plant was reduced to one leaf, which was trimmed to an approximate semicircle about ½ inch in diameter. The plant was then placed in a 2-ounce, round, narrow-mouthed bottle containing nutrient solution. A piece of paper was wrapped around each bottle and held in place with a rubber band to prevent formation of algae inside the bottle and to provide a convenient means of numbering and dating. The solution was changed weekly. The mites were transferred from the culture to the test plant by means of a single hair from a No. 10 camel's-hair brush glued to an insect pin that had been run through the eraser of a lead pencil so that it projected about ¼ inch at a convenient angle.

Female mites were isolated on individual seedlings for 6 to 12 hours, or until eggs were observed, and then removed. The eggs were examined 3 to 4 times daily, and as soon as hatching was observed the larvae were transferred to plants prepared as described above. Observations were then made twice daily, if possible, and the time spent in each stage was recorded. When a larva was found in a quiescent stage, a circle was drawn around it on the leaf with a sharp needle or pencil to facilitate finding either the larva or the cast skin on the next routine examination.

To determine the length of adult life and the number of eggs laid, daily observations were made. Some of the females were allowed to mate immediately; others were left unmated so that the length of adult life and egg-laying capacity could be compared. Eggs from unmated females produced only males.

RESULTS OF EXPERIMENTS.—Thirteen experiments were conducted on the life history of *desertorum* and six on that of *bimaculatus*. The data are summarized in table 1.

For *desertorum* a temperature of 85° F. and a relative humidity of 40 per cent are very nearly optimum. Limited observations indicate that this may not be true for other mites that attack cotton, particularly *bimaculatus*, which is more often of economic importance in the Southern and Southeastern States, where the rainfall and humidity are higher than in the Southwest. This perhaps explains why *desertorum* is more important than other spider mites in the arid Southwest.

There were found to be eight stages in the life cycle of both species: (1) egg, (2) larva, (3) quiescent, (4) protonymph, (5)

[1] Now at McNeese State College, Lake Charles, La.

Table 1.—Life-history records on two species of spider mites on seedling cotton growing in nutrient solution in the laboratory. College Station, Texas.

Experiment No.	Dates Conducted	Mean Temperature (°F.)	Mean Humidity (Per Cent)	Number of Mites	Average Length of Stage (Days)			
					Egg	Larva	Protonymph	Deutonymph
			Tetranychus desertorum					
	1948							
1	Feb. 24–Mar. 6	81.0	51.0	5	4.4	1.6	2.0	2.0
2	Mar. 7–25	81.5	46.5	14	5.1	2.0	2.2	1.9
3	Mar. 21–Apr. 2	76.0	46.0	28	3.9	2.0	1.9	3.0
4	Apr. 2–13	77.0	60.0	39	4.0	1.7	1.2	1.8
5	Apr. 14–25	78.0	50.0	29	4.2	1.8	1.6	1.7
6	Apr. 27–May 8	82.0	56.5	33	3.8	1.2	1.7	1.9
7	May 7–20	80.0	52.0	17	3.8	1.9	1.9	1.7
8	May 20–31	85.0	50.0	31	3.1	1.7	1.7	1.8
9	Aug. 3–Mar. 11	92.0	40.0	17	2.2	2.0	1.5	1.4
	1949							
10	June 8–15	84.4	50.4	30	3.0	1.0	1.1	1.7
11	June 18–24	91.4	42.2	30	1.9	1.0	1.1	1.9
12	July 9–16	90.5	44.3	30	2.0	1.4	1.2	1.6
13	July 21–26	90.5	42.7	25	2.0	1.0	1.4	1.5
Total or average		83.8	48.6	328	3.3	1.6	1.6	1.8
			Tetranychus bimaculatus					
	1948							
1	May 20–31	85.0	50.0	20	3.0	1.8	2.0	2.0
2	June 12–19	88.0	42.0	16	2.6	1.7	1.2	1.4
	1949							
3	June 8–15	84.4	50.4	32	2.0	1.8	1.1	1.2
4	June 18–24	91.4	42.2	25	1.6	1.0	1.2	1.3
5	July 9–17	90.5	44.3	30	2.3	1.8	1.0	1.6
6	July 19–26	90.5	42.7	25	2.0	1.0	1.2	1.7
Total or average		88.3	45.3	148	2.2	1.5	1.3	1.5

quiescent, (6) deutonymph, (7) quiescent, and (8) adult. The time from egg to adult averaged 8.3 days, ranging from 5.8 to 11.2, for *desertorum*, and averaged 6.6 days, ranging from 5.1 to 8.8, for *bimaculatus*. In each species both males and females passed through the same stages. In this respect these species are different from *Tetranychus telarius* (L.), the male of which, according to McGregor & McDonough (1917), had only one nymphal stage.

HABITS OF *Tetranychus desertorum*.—In an attempt to determine whether all fertilized *desertorum* eggs produced females, observations were made on 21 newly emerged females. From 28 eggs selected at random from the first group deposited by these females, in all of which mating had been observed, 3 males and 25 females were obtained. The time between mating of the first and last female was about 4 hours. In an effort to eliminate this variable, 11 females were taken from a mite culture just as they were emerging from the last nymphal skin and allowed to mate immediately. Each female was then placed on a separate plant and moved to a fresh one from time to time so that none of her progeny would be mistaken for the test mite. On the average 36 females to 10 males were obtained as a result of this experiment.

This experiment did not show that all fertilized eggs produce only females. Even though the females were mated, there was no proof that the eggs were fertilized. It was determined, however, that mated females produce a preponderance of females. The balance in nature is undoubtedly regulated by the production of only males from unmated females.

In one experiment females were mated 1 to 2 days after becoming adults. From the eggs deposited on the day of mating the ratio of the progeny was 3 females to 2 males.

It was observed that a female usually

mates with only one male, but if other males are in the vicinity she will mate with several. Moreover, several females were observed to mate as many as four times, and some of them twice with the same male. It was previously thought that males would pitch battle to determine which would mate with the female. Several males were often observed around a single female, but there was no noticeable battle. One male simply pushed the other male aside.

An examination of leaves containing spider mites in all stages of development showed many quiescent deutonymphs attended by one or more males. When several of these males were placed on a leaf containing quiescent deutonymphs reared from infertile eggs, they performed the same maneuvers.

Mating usually takes place immediately after the last nymphal skin is shed. After the female reaches full maturity, mating is difficult because of the smaller size of the male. Mating is accomplished somewhat as follows: The male approaches the female, who remains still with the afterportion of her abdomen raised, clasps her hind pair of legs with his fore pair, and curls the afterportion of his abdomen around backward and engages the female. The mating act lasts 30 to 50 seconds and may be repeated.

In an effort to determine whether *desertorum* and *bimaculatus* were distinct species or only varieties of the same, males of *desertorum* were mated to females of *bimaculatus*, and males of *bimaculatus* to females of *desertorum*. In both cases mating was accomplished with difficulty, but copulation did occur. True interlocking of the aedeagus of the male with the female did not usually take place, however, the act most often being a series of short attempts, but when interlocking did occur, the mating act lasted the normal period. In no case, however, did eggs from females thus mated produce females. Therefore, it can be assumed that true crossbreeding did not take place, and this is a strong point in favor of recognizing these two mites as distinct species.

SUMMARY.—Thirteen complete series of life-history data were obtained on *Tetranychus desertorum* Banks, with a total of 328 individuals. The time required from egg to adult averaged 8.3 days, ranging from 5.9 to 11.2.

Six complete series of life-history data were obtained on *Tetranychus bimaculatus* Harvey, with a total of 148 individuals. The time required from egg to adult averaged 6.6 days, ranging from 5.1 to 8.8.

Under the conditions of these experiments both sexes of *desertorum* and *bimaculatus* were found to have two nymphal instars. This is at variance with previously published data on the male of *Tetranychus telarius* (L.), which was reported to have but one nymphal instar.

The mating act of *desertorum* was observed and is described. Copulation occurred between males of *desertorum* and females of *bimaculatus* and between females of *desertorum* and males of *bimaculatus*, but eggs from females thus mated produced only males.

LITERATURE CITED

Garman, Philip. 1923a. The European Red Mite. Conn. Agr. Expt. Sta. Bul. 252: 101–25.

Garman, Philip. 1923b. Notes on the Life History of the Spruce Mite, *Paratetranychus ununquis* Jacobi. Conn. Agr. Expt. Sta. Bul. 247: 340–2.

McGregor, E. A., and F. L. McDonough. 1917. The Red Spider on Cotton. U. S. Dept. Agr. Bul. 416

Melvin, Roy, and Hilton H. Earle, Jr. 1948. A New Evaluation Method for Acaricides Using the Red Spider Mite. JOUR. ECON. ENT. 41: 901–2.

Metcalf, Robert L. 1948. Acaricidal Properties of Organic Compounds Related to DDT. JOUR. ECON. ENT. 41: 875–92.

Siegler, E. H. 1947. Leaf-Disk Technique for Laboratory Tests of Acaricides. JOUR. ECON. ENT. 40: 280.

Milky Diseases of European Chafer Larvae

H. TASHIRO and R. T. WHITE,[1] *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Two pathogenic bacteria, *Bacillus popilliae* Dutky and *lentimorbus* Dutky, are important biological control agents of the Japanese beetle, *Popillia japonica* Newm. They have been designated, respectively, as the type A and type B milky disease organisms. Since the life history and larval habits of the European chafer, *Amphimallon majalis* (Razoum.) (Gambrell 1943, Schwardt & Whitcomb 1943), are similar to those of the Japanese beetle, it appeared that these milky disease organisms might be of value in the biological control of the chafer. This paper summarizes the investigation of these organisms in relation to the European chafer until 1954.

Wheeler (1946)[2] first investigated the pathogenicity of milky disease organisms to European chafer larvae in laboratory and field tests. *Bacillus lentimorbus* indicated a low degree of pathogenicity when injected at the rate of 25,000 spores per larva. The regular type A and the *anxia* strains of *popilliae* exhibited a high order of virulence when injected at similar dosage levels. With soil inoculated at rates from 2 to 12 billion spores per kilogram and larvae incubated in this soil at 30° C., a low incidence of disease was obtained. Wheeler established plots on two farms by inoculating the soil with extremely heavy dosages of the type A and type A *anxia* strains and recovered infected larvae from these plots 5 months later. He also inoculated two ½-acre plots with spore dust standardized to contain 100 million spores per gram with a 2-gram discharge at intervals of 5 by 5 feet, which is the standard treatment for Japanese beetle work. Soil surveys in these plots during the 4 years following treatment revealed no diseased larvae.

LABORATORY TESTS.—Spore injection and feeding tests were conducted by the authors during the last 2 years with two possible strains of the type B and three of the type A organism. The blood of all larvae showing gross symptoms of disease was examined microscopically to confirm presence of the disease organism as well as to determine whether infection was with the intended species. Blood of larvae suspected of being infected and that of dead individuals were examined similarly. Determination of both types of organisms is possible from morphological differences, but their identification as to strains has not been possible by microscopic examinations.

Spore-injection tests.—Four possible strains of milky disease organisms were tested against third-instar larvae to study dosage-infection relationships. Two of them were the regular type B and type A strains of *Bacillus lentimorbus* and *popilliae*, which have been used in Japanese beetle work. An organism tentatively called the type B *Amphimallon* strain and one called the type A Stanton strain were also used. The source of the last two strains is discussed under FIELD STUDIES, *Natural disease areas.*

Spores were washed from slides of dried-blood films and the original suspensions then adjusted to contain approximately 300 million spores per cubic centimeter of sterile distilled water according to the directions given by Dutky (1942). Dilutions were made of the organisms except the regular type B so that these suspensions contained 3 thousand to 300 million spores per cubic centimeter. Since preliminary tests indicated a low incidence of disease with the regular type B strain, only the highest dosage was employed. On an average 0.0035 ml. of each suspension was injected into the haemocoele of the larvae with a microinjector (Dutky 1942). Injection was along the dorso-lateral region of the sixth and seventh abdominal segments. For each treatment 25 larvae were injected and held separately in 3-ounce tins in moist soil containing germinating grass and clover seed as food. Checks included 25 larvae injected with sterile distilled water and 25 noninjected larvae. All were incubated at a constant temperature of 80° F. Weekly examinations were made. Additional seed and water were added when needed to maintain optimum conditions for the

[1] The authors are grateful for the use of the laboratory facilities of Cornell University, New York State Agricultural Experiment Station, Geneva, N. Y.

[2] Wheeler, E. H. 1946. The pathogenicity of *Bacillus lentimorbus* Dutky and strains of *Bacillus popilliae* Dutky to larvae of *Amphimallon majalis* (Razoumowski), Scarabaeidae. Ph.D. thesis, Cornell University, 62 pp.

Table 1.—Dosage-infection relationships of milky disease organisms injected into third-instar European chafer larvae.

Organism	Number of Spores per Larva	Per Cent of Larvae Diseased After—		
		1 week	2 weeks	3 weeks
Type B regular	10^6	0	5	7
Amphimallon	10^5	0	7	7
	10^4	7	15	15
	10^3	12	25	30
	10^2	11	43	51
	10^1	21	57	73
	10^0	12	95	100
Type A regular	10^5	0	0	5
	10^4	0	15	33
	10^3	0	13	23
	10^2	0	33	57
	10^1	5	59	95
	10^0	10	100	100
Stanton	10^5	0	3	11
	10^4	0	5	7
	10^3	3	7	17
	10^2	19	53	83
	10^1	25	68	89
	10^0	39	100	100
Checks (injected and noninjected)—		0	0	0

larvae. The test was repeated under identical conditions. Table 1 presents the results of both tests.

The results indicated a low order of virulence of the regular type B strain, but a high order of virulence of the type B *Amphimallon* strain and both type A strains to larvae injected at rates of 10^4 or more spores per individual. Disease development was more rapid with type B *Amphimallon* and type A Stanton strains than with the regular type A strain. Greatest incidence of disease occurred during the second week of incubation and gradually decreased thereafter.

Spore-injection tests to study temperature-infection relationships among the type B *Amphimallon*, type A, and type A Stanton strains were conducted with injections at the rate of approximately 10^5 spores per larva and with incubation at 60°, 70°, 80°, and 90° F. Preparation of spore suspensions and injection techniques employed were the same as in the dosage-infection tests. As before, 25 larvae were held separately for each treatment. Weekly examinations were made of each larva at all temperatures. Seed and water were added as needed to maintain optimum conditions for the larvae. Table 2 summarizes the results of two such tests. Larvae in the first test were held for 6 weeks, but those in the second test were held for only 3 weeks. Therefore, the figures given for the sixth week are the results of one test.

The rate of infection with all three strains increased with the temperature. Infection was obtained at 60° F., but not until the sixth week. At 70° the numbers of larvae infected with type B *Amphimallon* and type A Stanton strains were significantly higher than with the regular type A strain. This trend was apparent also at 80°. The three strains reacted similarly at 90°.

Feeding tests.—Preliminary feeding tests were made by incubating third-instar larvae at 75°–80° F. in soil inoculated at the rate of 2 billion spores per kilogram. Diseased individuals were present within 2 weeks in soil inoculated with type B *Amphimallon* and type A regular and *anxia* strains. After 3 weeks, 79 to 85 per cent infection was obtained with all three strains. Thirty-four per cent of the larvae became diseased in soil treated with regular type B spores, but all were infected with a type A organism. On the basis of these results further feeding tests were conducted with the four organisms to study dosage-infection relationships in third-instar larvae.

Spore dust standardized to contain 100 million spores per gram was thoroughly mixed with screened soil at rates of 2.5, 5, 10, and 20 grams per kilogram to give inoculation dosages of 0.25, 0.5, 1, and 2 billion spores per kilogram of soil. Only the highest dosage was used with the regular type B organisms. Twenty-five larvae per treatment, including checks in untreated soil, were held separately in 3-ounce tins of soil. They were incubated at 75°–80° F. Larvae were examined at weekly intervals for 5 weeks. Seed and

Table 2.—Temperature-infection relationships of milky disease organisms injected at the rate of 10^5 spores per third-instar European chafer larva.

Incubation Temperature (° F.)	Organism	Per Cent of Larvae Diseased After—			
		1 Week	2 Weeks	3 Weeks	6 Weeks
60	Type B *Amphimallon*	0	0	0	25
	A regular	0	0	0	5
	Stanton	0	0	0	11
	Check	0	0	0	0
70	Type B *Amphimallon*	0	35	75	89
	A regular	0	21	45	70
	Stanton	2	67	93	100
	Check	0	0	0	0
80	Type B *Amphimallon*	21	85	100	100
	A regular	25	85	87	87
	Stanton	49	95	100	100
	Check	0	0	0	0
90	Type B *Amphimallon*	43	97	100	100
	A regular	43	75	97	100
	Stanton	63	93	97	100
	Check	0	0	0	0

Table 3.—Dosage-infection relationships of milky disease organisms ingested by third-instar European chafer larvae.

Organism	Billions of Spores per Kilogram of Soil	Per Cent of Larvae Diseased After—			
		1 Week	2 Weeks	3 Weeks	4 Weeks
Type B regular	2	0	22	26	28
Amphimallon	0.25	0	21	32	40
	.5	0	27	30	35
	1	2	37	44	45
	2	0	42	57	62
Type A regular	.25	0	28	41	47
	.5	6	40	49	58
	1	0	37	61	70
	2	8	49	57	57
anxia	.25	0	30	39	49
	.5	2	37	44	56
	1	0	26	30	31
	2	2	34	39	41
Check	—	0	0	0	0

water were added as needed to maintain proper conditions for the larvae. Table 3 summarizes the results of two such tests.

Incidence of disease was the lowest with the regular type B strain, and larvae infected with both type B and type A strains were present. With the other strains infection occurred during the first week with the greatest increase in infection during the second week of incubation. These three organisms produced similar degrees of infection. There was no correlation between spore dosage and incidence of diseased larvae. Higher rates of infection were obtained in the preliminary test, but they may have been caused by the use of younger larvae. By the time the dosage-infection tests were conducted, larvae were older and may have fed less vigorously.

FIELD STUDIES.—*Field inoculations.*—In 1945 Wheeler (1946)[2] established milky disease plots on two farms, Eckert and DeBryne, near Newark, N. Y. On each farm four plots 15 by 15 feet were treated, two with the type A regular and two with type A *anxia* strain at rates of 2 and 4 billion spores per square foot. Spores for these treatments were obtained by injecting third-instar European chafer larvae and holding them until disease developed. In determining spore concentrations it was estimated that each diseased larva contained 2 billion spores. The larvae were ground and applied to the soil as spore suspensions.

In July 1950 the authors treated five other plots using type A and type B spore dust. Applications conformed to methods normally used in soil inoculation for Japanese beetle work, that is, spot treatment at intervals of 3 by 3 or 5 by 5 feet, with discharges of approximately 2 grams of standard spore dust per spot. Since diseased larvae were recovered from some of these plots, six additional plots were treated in April 1951 with the type A regular and *anxia* strains. Type B *Amphimallon* spore dust was applied to four additional plots in May 1953. The large numbers of third-instar larvae found infected with this organism in two natural disease areas in June 1951 (see next section) were taken to the Moorestown, N. J., laboratory. Spores from these larvae were injected into Japanese beetle larvae, and those becoming diseased with this organism were used to prepare this spore dust.

Natural disease areas.—During the milky disease surveys and while larvae were being dug for various other purposes, many diseased larvae were found in three locations where spore dust was not applied.

During the first week of June 1951, while third-instar larvae were being dug on an abandoned hillside on the Bedette farm at Port Gibson, N. Y., about 25 per cent of them were found diseased. The large number of third-instar larvae at this location at this time of the year was unusual, since practically all individuals in a normal population are pupae during early June. More intensive random diggings in this area on June 12 showed 95 per cent of the 185 grubs found to be infected. Similar random diggings 1½ miles away on the Rolland farm outside of a plot inoculated with regular type B spores revealed a similar situation. Of the 62 third-instar larvae dug, 80 per cent were diseased. Larvae from both locations were infected with an organism the spores of which resembled type B but acted more like the regular type A organism. Growth on artificial media more nearly resembled that of the type A organism. The temperature of the soil at the time of peak disease development coincided with that occurring in peak type A infections in Japanese beetle populations. This organism was tentatively called type B *Amphimallon* strain.[3] It was used in all

[2] Laboratory studies on this strain in artificial media and against *Popillia* larvae and preparation of experimental spore dust were performed by S. R. Dutky and J. V. Thompson, Japanese Beetle Laboratory, Moorestown, N. J.

laboratory tests described above as well as in field inoculations of four plots in May 1953.

A number of third-instar larvae collected from the Stanton farm in Marion, N. Y., during the latter part of April 1952 developed milky disease and were identified as being infected with a type A organism. Many of the second-instar larvae collected from the same pasture in August 1952 became diseased with a type A organism. This organism was tentatively called the type A Stanton strain and was used in the laboratory spore-injection tests.

Other diseased larvae were recovered in smaller numbers from various scattered locations during the last 3 years. Three third-instar larvae infected with type B and one with type A were found north of Newark, one infected with type A at Alloway, and a second-instar larva infected with type A at the Marion Cemetery. The last was found by F. L. Gambrell of the New York State Agricultural Experiment Station. Additional diseased third-instar larvae were recovered from other localities.

Field surveys of milky disease plots.—Since 1950 regular monthly diggings from May to November have been made in each plot as it was put out, in each natural disease area as it was discovered, and on the two farms where Dr. Wheeler established his disease plots. By this time it was no longer possible to determine the exact location of his small plots because many of the corner stakes had disappeared. However, since the disease had spread beyond the original boundaries of each plot, each field was considered as a plot. Surveys were made by the authors in these fields, which were designated merely as the DeBryne-Wheeler and Eckert-Wheeler plots.

Diggings during these months allowed examination of third-instar larvae, prepupae, and pupae of the passing generation, and eggs and first-, second-, and third-instar larvae of the following generation. Generally, 10 1-square-foot diggings were made in each survey, and normal larvae were retained in soil at room temperature to 80° F. for development of disease in infected individuals. Over 2,600 1-square-foot diggings have been made, and over 12,000 larvae have been examined from milky disease plots.

Diseased larvae have been recovered from all but 2 of the 17 disease plots that have been put out since 1945. One of the negative plots was treated in July 1950 in a pasture where the larval population was low and has been low since 1950. The other negative plot was treated in May 1953, and sufficient time may not have elapsed for disease development. In some of the plots the recovery of type B infected larvae from type A treated plots and vice versa has been rather frequent. Except in the surveys made in June 1951, when large numbers of larvae infected with the type B *Amphimallon* strain were recovered from the Bedette and Rolland farms, most of the diseased larvae recovered have been second-instars. By the last week of September practically all normal larvae are third-instars. Most of the second-instars collected during the latter half of September and October were infected with milky disease.

Diseased individuals have been recovered rather consistently in certain plots but not in others. The three areas where they have been consistently recovered and that show the greatest promise of control with milky disease have been the two areas of natural incidence of disease, the Rolland and Bedette farms, and the DeBryne plot established by Dr. Wheeler. Chafer larvae infected with milky disease were consistently recovered in the DeBryne plots by Dr. Wheeler through the spring of 1947, at which time surveys were discontinued (unpublished data). Surveys in this area were undertaken by the authors in 1950. Diggings made in these three areas have shown the incidence of disease as given in table 4. All spring surveys included diggings made into June until the population consisted mostly of adults. Fall surveys included diggings made since August after eggs of the new generation had hatched.

In Japanese beetle larvae milky disease does not become prevalent until the larval population is high, but as the disease develops the population drops to a low level and remains there (White 1941). This relationship was not so clear-cut in the areas of high disease incidence in European chafer larvae. However, in the DeBryne-Wheeler plot and Bedette hillside there has been a tendency to retention of fairly low populations. The Rolland pasture has not shown consistently low popu-

Table 4.—Population of European chafer larvae and incidence of disease, 1950–1953.

Time of Survey	Number of Square-Foot Diggings	Average Number of Larvae per Square Foot	Total Number of Larvae Examined	Per Cent Diseased
DeBryne-Wheeler plot				
1950, Fall	20	10.5	211	5.2
1951, Spring	20	2.1	43	30.0
Fall	20	1.8	37	32.4
1952, Spring	30	1.5	46	4.4
Fall	30	2.8	83	20.5
1953, Spring	30	2.1	63	6.4
Fall	50	4.2	208	27.8
Bedette hillside				
1950, Fall	10	17.0	171	0
1951, Spring	7	4.0	29	24.0
June 12[1]	—	—	185	95.0
Fall	10	3.0	30	0
1952, Spring	32	1.7	54	16.6
Fall	32	1.1	37	8.1
1953, Spring	30	1.7	52	9.7
Fall	50	4.0	203	6.5
Rolland pasture				
1951, Spring	20	12.3	225	0
June 12[1]	—	—	62	80.0
Fall	20	3.0	60	13.3
1952, Spring	30	4.7	141	.1
Fall	40	9.5	379	6.6
1953, Spring	36	3.7	132	6.1
Fall	40	7.1	285	5.3

[1] Special survey.

lations. In the DeBryne-Wheeler plot the incidence of disease was higher in the fall than in the spring. This trend was not present in the other two areas, where infection was with the type B *Amphimallon* strain.

DISCUSSION.—Beard (1944) obtained 85 to 90 per cent infection in third-instar Japanese beetle larvae that were injected with approximately 100,000 spores of type A organism and incubated for 2 weeks at approximately 80° F. Wheeler (1946)[2] obtained 69 per cent and the authors 59 to 95 per cent infection in third-instar European chafer larvae injected with a similar spore dosage and incubated under the same conditions.

In feeding tests Beard (1944) obtained approximately 50 per cent infection of third-instar Japanese beetle larvae when incubated for 2½ weeks at 78° F. in soil inoculated at the rate of approximately 2 billion spores of the regular type A organism per kilogram. The authors obtained slightly over 50 per cent infection of third-instar European chafer larvae when exposed to the same conditions. Results of both injection and feeding tests indicate that the European chafer larvae are as susceptible to the type A milky disease organism as are the Japanese beetle larvae.

In the field results have not been so promising, and in general the increase in disease incidence has been much slower than against Japanese beetle larvae. White (1941) reports that populations of Japanese beetle larvae in central New Jersey and south into Maryland have been reduced to as much as one-fifth to one-sixth the original, and that the disease incidence has increased from less than 10 per cent to over 60 per cent of the population within 12 months. with no subsequent build-up of the population. According to White & Dutky (1940), the period of disease development in Japanese beetle larvae when the soil temperature is above 60° F. extends from the middle of May to about the middle of October in the vicinity of Moorestown, N. J. (latitude of Philadelphia, Pa.). Adams & Wheeler (1946) state that under the climatic conditions of Poughkeepsie, N. Y., the reduction of population to a point of satisfactory control requires about 4 years with a dosage of 2 pounds of standard spore dust per acre. Increasing the spore dosage to 2,000 pounds per acre can give the same control in 2 years.

A comparison of the results obtained in different parts of the country indicates that soil temperature while the insects are in the larval stage must determine whether adequate control is obtained or not. The rate of disease development in European chafer larvae is similar to that in Japanese beetle larvae at the more northern latitudes.

In view of the high rates of infection obtained in European chafer larvae in the laboratory and the temperature requirements for adequate disease development in the field, it appears likely that these larvae may be as susceptible to milky disease as are Japanese beetle larvae. Failure to obtain higher incidence of disease in the field may be due to the soil temperatures. There are two possible explanations for the presence of the disease in several areas where spore dusts was not distributed. The milky disease organisms may have been spread by birds, since large flocks of starlings have been observed feeding on chafer larvae. Their droppings deposited in other areas of high larval population could cause the development of the disease. There could be milky disease organisms indigenous to the area which are pathogenic to European chafer

larvae. The occasional recovery of *Phyllophaga* larvae infected with milky disease suggests this possibility. At any rate, milky disease organisms pathogenic to European chafer larvae appear to be rather widely distributed.

SUMMARY.—The susceptibility of larvae of the European chafer, *Amphimallon majalis* (Razoum.), to the milky disease organisms *Bacillus popillae* Dutky and *lentimorbus* Dutky has been demonstrated As judged by two methods of infection, spore injection and spore ingestion, the virulence of the regular type A strain is of the same order of pathogenicity to European chafer larvae as to Japanese beetle larvae.

Three possible strains of *popilliae* and two of *lentimorbus* were tested in the laboratory. The regular type B strain of *lentimorbus* exhibited low pathogenicity to chafer larvae by both methods of infection. Type B *Amphimallon* and the type A strains were highly pathogenic by both methods.

Type B *Amphimallon*, regular type A, and type A Stanton strains infected 95 to 100 per cent of the larvae 2 weeks after being injected with a million spores. The rate of infection was directly related to the incubation temperatures, infected larvae being obtained in 6 weeks at 60° F., in 2 weeks at 70°, and in 1 week at 80° and 90°. Type B *Amphimallon* and type A Stanton strains caused disease to develop more rapidly and to a slightly higher incidence than the regular type A strain.

In feeding tests there were no differences in disease incidence among type B *Amphimallon*, regular type A, and type A *anxia* strains. There was no correlation between incidence of disease and concentration of spores in the soil, from 31 to 70 per cent of the larvae becoming infected after 4 weeks of incubation.

Diseased larvae have been recovered from 15 of the 17 plots where milky disease spores have been distributed since 1945. Three other areas have been discovered where the disease has occurred naturally and infected larvae have been recovered consistently. The tentatively named type B *Amphimallon* strain was the causal organism in two of these areas in Port Gibson, N. Y., where 80 and 95 per cent of the third-instar larvae were found diseased early in June 1951. Larvae infected with type A spores were first recovered in 1952 on the Stanton farm, Marion, N. Y. This organism has been tentatively called type A Stanton strain. Disease incidence has been high in the DeBryne-Wheeler plot since 1951. Diseased larvae have also been recovered from areas not treated with milky disease organisms.

When all factors are considered, there is promise of obtaining economic control of European chafer larvae through the use of milky disease.

LITERATURE CITED

Adams, J. A., and E. H. Wheeler. 1946. Rate of development of milky disease in Japanese beetle populations. JOUR. ECON. ENT. **39**(2): 248–54.

Beard, Raimon L. 1944. Susceptibility of Japanese beetle larvae to *Bacillus popilliae*. JOUR. ECON. ENT. **37**(5): 702–8.

Dutky, S. R. 1942. Method for the preparation of spore-dust mixtures of type A milky disease of Japanese beetle larvae for field inoculation. U. S. Bur. Ent. and Plant. Quar. **ET-192.**

Gambrell, F. L. 1943. Observations on the economic importance and control of the European chafer. N. Y. State Agr. Expt. Sta. Bul. **703**: 8–13.

Schwardt, H. H., and W. H. Whitcomb. 1943. Life history of the European chafer, *Amphimallon majalis* (Razoum.). JOUR. ECON. ENT. **36**(2): 345–6.

White, R. T. 1941. Development of milky disease on Japanese beetle larvae under field conditions. JOUR. ECON. ENT. **34**(2): 213–5.

White, R. T., and S. R. Dutky. 1940. Effect of the introduction of milky diseases on populations of Japanese beetle larvae. JOUR. ECON. ENT. **33**(2): 306–9.

Field Evaluation of Insecticides against Codling Moth[1]

E. H. Glass, *N. Y. State Agr. Expt. Sta., Geneva*

During 1953 there was enough codling moth activity in a few New York apple orchards to suggest the possibility that DDT was losing its original effectiveness for control of this pest. This paper does not cover the subject of codling moth resistance to DDT but the data presented would be useful should it ultimately be necessary to substitute some other insecticide for DDT for codling moth control.

With the introduction and wide scale use of DDT in apple orchards, codling moth populations have been too low for satisfactory field testing of insecticides in commercial orchards. Even unsprayed check trees were not heavily infested when DDT was used on nearby trees. However, field testing work has been done in two Experiment Station orchards at Geneva where the codling moth populations have been maintained at a high level. By following good orchard practice, fruit production has been regular, apple scab control adequate and pests other than codling moth have been held in check. Only one-third to one-half the trees have been used for codling moth control tests in any 1 year. From 1948 through 1953 check tree infestations have ranged from 139 to 297 worms per 100 apples with nearly 100 per cent of the fruit wormy each year. Inasmuch as DDT has been used on only a small portion of the trees in these experimental orchards during any 1 year, conditions have not favored the development of DDT resistance in the population. There is no evidence that DDT resistance occurs here. A total of 160 treatments were evaluated against codling moth during the period reported.

In western New York the codling moth has on the average 1.3 generations each year. The spring brood moth flight begins in late May or early June and the first eggs hatch near mid-June. Second brood eggs begin hatching towards the last of July and continue into September. There is a period of about 1 week between broods when few eggs are hatching.

Procedure.—The problem of codling moth control in the experimental orchards at Geneva differs from that in commercial plantings primarily in the amount of second brood activity. Apple growers attempt to and in recent years have been successful in preventing second brood damage by almost eliminating the first brood. In these experimental orchards the large numbers of check trees result in heavy late season activity. Experience has shown that 2 pounds of 50 per cent DDT per 100 gallons controlled codling moth in the Station orchards when applied in three sprays against first brood and two against second. The interval between sprays has been 12 to 14 days. The exact spray dates for each season are given later. In New York, the first codling moth spray is applied about 3 weeks after petal fall and is termed the "first cover" even though one spray usually has been applied about 10 days after petal fall to control apple scab, plum curculio and red-banded leaf roller.

One of the experimental orchards is made up of 27 large Rhode Island Greening trees in three rows. The other orchard consists of 8 acres of interplanted McIntosh and Cortland trees. There are 16 rows made up of 27 trees each. The oldest trees in this latter orchard are about 20 years old except for a few much older trees of assorted varieties that have been retained as codling moth reservoirs. All spraying was done with a hydraulic sprayer using a spray gun from the ground at 500 pounds pressure. Enough spray was applied to thoroughly wet the entire tree.

Except in 1948, the experimental design has been controlled randomized blocks using single tree plots. Each treatment was replicated on three or four McIntosh, one Greening and two or three Cortland trees. Thus, there were 7 replicates except in 1951 and 1953 when there were insufficient Greening trees with a crop and only six replicates were used. In addition to these larger plots, certain new insecticides were tested on two McIntosh trees for preliminary screening of effectiveness against codling moth and for phytotoxicity.

Data on control of first brood have

[1] Journal Paper No. 968, New York State Agricultural Experiment Station, Geneva, N. Y., July 8, 1954.

been taken each year during the last week in July or the first week in August by examining 200 apples per tree for codling moth entries. Thus a total of 1200 or 1400 apples were examined per treatment. Drop apples were picked up and examined several times during the season and again after harvest. Harvest records on fruit injury were taken using methods similar to those reported by Newcomer & Dean (1943). For each tree, records were taken of the number of bushels of picked fruit and the number of apples in three representative bushels. Enough apples were removed from each bushel to make a total of 300 apples, and then each one was carefully examined for injuries. Each fruit was scored under the categories of: clean, stung, wormy or stung and wormy. Thus figures could be computed for various degrees of injuries. Further, the total number of stings and worm holes were recorded. The results are reported here as per cent wormy at the end of first brood and worms per 100 apples for the season. The per cent wormy for picked fruit is not too satisfactory because injured McIntosh apples drop more readily than do Cortland and Greening thus giving misleading figures for years when the Greening variety was not included in the experiment. Over-all seasonal control is best represented by the record of worms per 100 apples. Analysis of variance was computed for this statistic for each replicated experiment. The checks were omitted from the analysis.

SPRAY MATERIALS.—The materials used in these experiments, listed below, were standard brands and formulations of commercially available pesticides except as noted in the tables. As many of the chemicals do not have common names, that have been adopted by the committee on Insecticide Terminology these are listed with the most often used code name or number, the chemical name, and the manufacturer:

Aramite
Arathan. dinitro capryl phenyl crotonate. Rohm & Haas Co.
Bayer 21/116. 0,0-dimethyl 0-(2-(ethylmercapto)-ethyl) thiophosphate. Bayer (R. Geary).
Black Leaf 155. 14% "fixed" nicotine. Tobacco By-Products & Chemical Corp.
Black Leaf 253. 25% DDT 3% parathion. Tobacco By-Products & Chemical Corp.
Chlorobenzilate. 2-hydroxy-2,2-bis(4-chlorophenyl) ethyl acetate. Geigy Co., Inc.
Chlorthion. 0,0-dimethyl 0,3,chloro-4 nitrophenyl thiophosphate. Bayer (R. Geary).
CS-645A.
CS-674A.
CS-708.
CS-728. 2-nitro-1-phenyl 1-p-chlorophenyl butane. Commercial Solvents Corp.
Darco S 51. Activated carbon. Darco Corp.
Diazinon.
EPN.
ET-30. 73% malathion 5% parathion. American Cyanamid Co.
Isolan. 1-isopropyl-3 methyl-pyrazolyl-(5)-dimethylcarbamate. Geigy Co., Inc.
Metacide.
Nitrox. 0,0-dimethyl 0-paranitrophenyl thiophosphate. Chemagro Chemical Corp.
NPD. tetra-n-propyl dithionopyrophosphate. E. I. duPont deNemours & Co., Inc.
Nuchar C115N. Activated carbon. West Virginia Pulp and Paper Company.
Nuchar C115NA=agricultural grade. West Virginia Pulp and Paper Company.
Ovotran (K-6451). parachlorophenyl parachlorobenzene sulfonate. Dow Chemical Co.
Penfluor. fluorine analog of DDT. Pennsylvania Salt Co.
Potasan. diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin. Geary Chemical Corp.
Ryanexcel. 96% ryania 3% activator. S. B. Penick & Co.
Strobane. terpene polychlorinates (66% chlorine). B. F. Goodrich Chemical Company.
3869. S-carbamyl methyl 0,0-dimethyl dithiophosphate. American Cyanamid Co.
3901. S-mercaptoacetylurea 0,0-dimethyl dithiophosphate. American Cyanamid Co.
4018. S-(1,2-dicarbomethoxyethyl)0,0-diethyl dithiophosphate. American Cyanamid Co.
4124. 0-(2-chloro-4-nitrophenyl)0,0-dimethyl thiophosphate. American Cyanamid Co.
4389. S-(1,2-dicarbethoxy ethyl)0,0-dimethyl thiophosphate. American Cyanamid Co.

EXPERIMENTAL RESULTS.—Field tests were conducted from 1948 through 1953. The results for each season are presented separately.

1948 Test.—The plots for this test were different from the others in that there were only three blocks but with each treatment applied to three McIntosh trees in each block. There was only one Cortland tree per treatment. The results are given only as per cent wormy after first brood and again at harvest. The spray dates for the cover sprays were June 21, July 2, July 14, August 4 and August 16. The results are given in table 1.

The check plot was 30.7 per cent wormy at the end of first brood and the control in all treatments including lead arsenate was satisfactory. For the entire season 50 per cent DDT at 2 pounds per 100 gallons gave the best control. Lead arsenate and parathion were not satisfactory

as used. It was observed that most of the injury on the parathion plots resulted from late codling moth activity. Combinations of DDT or lead arsenate and ½ pound of 25 per cent parathion wettable powder were better than either alone at comparable dosages. The DDT and lead arsenate combination (Plot 8) was effective. The use of parathion in the first two or three cover sprays followed by DDT in the last three or two sprays produced good results as shown in Plots 9 and 10.

1949 Tests.—Unusually warm weather in 1949 favored codling moth, subjecting all treatments to a severe test. Even DDT was not too effective indicating that at least one more cover spray should have been used. The cover spray schedule was June 13, June 23, July 6, July 26 and August 10. The large plots were replicated on 4 McIntosh, 1 Greening and 2 Cortland trees. These data are given in table 2 and the results of the 2-tree plots in table 3.

None of the treatments were outstanding but it is of interest to note that DDT was superior to DDD and parathion and that all three gave better results than lead arsenate. Again most of the insect damage to the parathion plots occurred very late in the season. The addition of activated carbon to the parathion apparently did not affect control.

Several treatments (11 to 15) were evaluated to learn whether DDD or parathion could be substituted for DDT in certain sprays. The results indicate that substitutions can be made but control may not be quite as good. Practically, one substitution can be made in the next

Table 1.—Codling moth control at Geneva, N. Y., 1948.

Plot	Material and Pounds per 100 Gallons[1]	Per Cent Wormy Fruit	
		Aug. 3	Harvest
1	50% DDT, 2	0.2	1.9
2	50% DDT, 1	0.6	7.8
3	Lead arsenate, 3	0.8	11.4
4	25% parathion, 2	0.9	15.4
5	25% parathion, 1	0.4	17.0
6	Lead arsenate, 3 plus 25% parathion, 0.5	0.0	3.9
7	50% DDT 1 plus 25% parathion, 0.5	0.0	4.8
8	50% DDT, 1 plus lead arsenate, 2	0.0	2.6
9	25% parathion (1, 2), 1 50% DDT (3, 4, 5), 2	0.4	2.7
10	25% parathion (1, 2, 3), 1 50% DDT (4, 5), 2	0.4	2.7
11	Check (fungicide only)	30.7	67.1

[1] Figures in parentheses indicate material applied only in those cover sprays.

Table 2.—Codling moth control at Geneva, N. Y., 1949.

Plot	Material and Pounds per 100 Gallons[1]	Per Cent Wormy July 25	Worms per 100 Apples
1	50% DDT, 2	1	25
2	50% DDT (1, 2, 3, 4), 2 50% DDT (5), 1	—	25
3	50% DDT (1, 2, 3, 4), 2 50% DDT[2] (5), 2	—	28
4	50% DDT (1, 2, 3, 4), 2 *Black Leaf 155* (5), 3	—	45
5	50% DDT,[3] 2	8	49
6	50% DDD, 2	6	67
7	25% DDD emuls.[4]	8	97
8	Lead arsenate, 3	5	104
9	25% parathion, 1	1	30
10	25% parathion, 1 plus *Darco S 51*, 1	2	29
11	50% DDT (1, 2, 3), 2 25% (parathion (4, 5), 1	—	38
12	50% DDT (1, 2, 3), 2 50% DDD (4, 5), 2	—	55
13	50% DDT (1, 2, 3), 2 25% DDD emuls.[4] (4, 5)	—	70
14	50% DDT (1, 2, 3, 5), 2 50% DDD (4), 2	—	36
15	50% DDT (1, 2, 3, 5), 2 25% parathion (4), 1	—	36
16	Check	53	202
	L.S.D. (19:1)		20
	L.S.D. (99:1)		27

[1] Figures in parentheses indicate material applied only in those cover sprays.
[2] Experimental formulation with DDT impregnated on tobacco filler.
[3] Only three sprays applied: June 20, 30 and July 27.
[4] Used 1 quart per 100 gallons.

Table 3.—Codling moth control at Geneva, N. Y., in two-tree plots, 1949.

Plot	Material and Pounds per 100 Gallons	Per Cent Wormy July 25	Worms per 100 Apples
1	25% aldrin, 2	32	—[1]
2	25% *3869*, 2	44	—
3	25% *3901*, 2	30	—
4	15% Aramite, 1	26	92
5	25% *Arathan* emuls.[2]	55	—
6	50% *Ovotran*, 2	47	127
7	25% CS-645[2]	6	30
8	31.5% EPN, 1	10	72
9	50% *Penflour*, 2	—	89
10	Check	53	202

[1] All fruit dropped prior to harvest due to codling moth injury. No records taken.
[2] Used 1 quart per 100 gallons.

Table 4.—Codling moth control at Geneva, N. Y., 1950.

Plot	Material and Pounds per 100 Gallons[1]	Per Cent Wormy July 31	Worms per 100 Apples
1	50% DDT, 2	1	1
2	50% DDT, 1	2	3
3	50% DDD, 2	3	6
4	50% CS-708, 2	1	2
5	50% methoxychlor, 2	4	3
6	Lead arsenate, 3	5	18
7	15% parathion, 2	1	5
8	15% parathion, 1	1.1	8
9	15% parathion, 2 plus *Nuchar C-115N*, 1	1	3
10	15% parathion, 1 plus *Nuchar C-115N*, 0.5	1	5
11	30% EPN, 1	1	5
12	50% DDT, 1 plus 15% parathion, 1	1	1
13	50% DDT, 1 plus 30% EPN, 0.5	1	2
14	50% DDT (1, 2, 3, 5), 1 15% parathion (4), 1	1	1
15	50% DDT, 2 plus 15% parathion,[2], 1	1	3
16	Check	28	145
	L.S.D. (19:1)		5
	L.S.D. (99:1)		6

[1] Figures in parentheses indicate material applied only in those cover sprays.
[2] Only three sprays, applied June 22, July 11 and Aug. 18.

to the last spray as shown in Plots 14 and 15. *Black Leaf 155* was not a satisfactory substitute for DDT in the last spray (Plot 4).

As shown in table 3, several of the materials tested had little or no value for codling moth control. These include aldrin, *3869*, *3901*, Aramite, *Arathan* and *Ovotran*. The CS-645A was the only product that was as effective as DDT.

1950 Tests.—The temperatures during the months of June, July and August were about normal. The five cover sprays were applied on June 16, 28, July 12, August 7 and 18. The large plots consisted of 4 McIntosh, 1 Greening and 2 Cortland trees. The results are given in tables 4 and 5.

DDT, DDD, methoxychlor, CS-708, parathion and EPN all gave satisfactory codling moth control in 1950 but DDT was still the best. Lead arsenate was significantly poorer than all the other treatments. Parathion plus the activated carbon gave as good as or better control than when used alone. Combinations of DDT and parathion or EPN again appeared promising. In Plot 15 a combination of DDT and parathion was used in an abbreviated schedule to see if three sprays might be effective due to the residual effectiveness of DDT and the killing of larvae in the fruit with parathion. As expected there were many large stings on the fruit from this plot but the over-all control was good. This program might be useful for certain situations but not generally in New York because it would not afford control of apple maggot.

In the small plots, CS-674A gave the best control. The CS-645A was effective but appeared weaker than in 1949 in relation to DDT. Experimental materials *4018* and *4124* were poor even though high dosages were used. Metacide, malathion and demeton were not effective during the latter part of the season.

1951 Tests.—Like 1950 seasonal temperatures in 1951 were normal. The cover spray schedule followed was June 19, July 3, July 17, August 6 and 17. Treatments were replicated 4 times on McIntosh and 2 times on Cortland. The results are given in tables 6 and 7.

Except for lead arsenate, results with most schedules were satisfactory. The phosphates gave good control particularly during the early part of the season. Again activated carbon did not reduce the effectiveness of parathion. In the small plots, the 75 per cent DDT and the 50 per cent DDT paste were as good as the standard 50 per cent DDT wettable powder. Q-137 was very weak at the 2 pounds of 25 per cent powder per 100 gallons. *CS-728* was not as good as *CS-708*. Demeton was not very effective, particularly in the liquid formulation. *Potasan* performed similarly to parathion.

Table 5.—Codling moth control at Geneva, N. Y. in two-tree plots, 1950.

Plot	Material and Quantity per 100 Gallons	Per Cent Wormy July 31	Worms per 100 Apples
1	50% Q-137, 2 lbs.	3	20
2	50% CS-645A, 2 lbs.	8	23
3	50% CS-674A, 2 lbs.	1	3
4	33% Metacide, 1 pt.	1	11
5	47% *4018* emuls., 1 qt.	3	49
6	25% *4124* emuls., 2 qts.	1	36
7	25% malathion, 2 lbs.	3	16
8	32% demeton, 1 qt.	2	23
9	Check	28	145

Table 6.—Codling moth control at Geneva, N. Y. 1951.

Plot	Material and Pounds per 100 Gallons[1]	Per Cent Wormy July 30	Worms per 100 Apples
1	50% DDT, 2	1	2
2	50% DDT, 1	6	14
3	50% methoxychlor, 2	1	6
4	50% CS-708,[2] 2	2	3
5	Lead arsenate, 3	9	40
6	15% parathion, 2	1	3
7	15% parathion, 1	1	12
8	15% parathion, 2 plus *Nuchar C-115N*, 1	1	3
9	15% parathion, 1 plus *Nuchar C-115N*, 0.5	1	4
10	15% parathion, 2 plus *Nuchar FAN*, 1	1	2
11	25% malathion, 2	2	13
12	50% malathion emuls.[3]	1	5
13	50% DDT, 1 plus 25% EPN, 0.25	1	7
14	50% DDT (1, 2, 3), 1 plus 15% parathion (4, 5), 0.5	4	9
15	Check	44	206
	L.S.D. (19:1)		10
	L.S.D. (99:1)		13

[1] Figures in parentheses indicate material applied only in those cover sprays.
[2] Later chemical analysis indicated only 34.9% CS-708.
[3] One pint per 100 gallons.

1952 Tests.—The large plot treatments were applied to 4 McIntosh, 1 Greening and 2 Cortland trees. The seasonal temperatures were above average in July but otherwise nearly normal. Cover spray dates were June 16, 30, July 14, 30 and August 13. The results are given in tables 8 and 9.

All treatments containing DDT, either at the regular strength of 1 pound actual per 100 gallons or at half strength performed very well. The addition of parathion either in the tank or in the formulation (*Black Leaf 253*) did not change the control significantly. The methoxychlor-parathion combination was effective. As shown in plots 14 and 15 parathion at ½ pound per 100 gallons plus Q-137 or DDD

Table 7.—Codling moth control at Geneva, N. Y. in 2 tree plots, 1951.

Plot	Material and Quantity per 100 Gallons	Per Cent Wormy July 30	Worms per 100 Apples
1	75% DDT, ⅔ lb.	10	12
2	50% DDT paste, 1 lb.	11	7
3	25% Q-137, 2 lbs.	29	114
4	25% *CS-728* emuls., 2 qts.	20	25
5	50% demeton emuls., ¼ pt.	16	61
6	25% demeton, 1¼ lbs.	3	25
7	32% *Potasan* emuls., ¾ pt.	1	7
8	Check	44	206

Table 8.—Codling moth control at Geneva, N. Y. 1952.

Plot	Material and Pounds per 100 Gallons	Per Cent Wormy July 31	Worms per 100 Apples
1	75% DDT, 1.3	1	7
2	75% DDT, 0.66	1	5
3	15% parathion, 2 plus *Nuchar C-115NA*, 1.5	1	6
4	15% parathion, 1 plus *Nuchar C-115NA*, 0.75	2	11
5	15% parathion, 0.5 plus *Nuchar C-115NA*, 0.38	3	32
6	25% malathion, 2	3	29
7	50% malathion emuls.[1]	4	29
8	*ET-30*[2]	2	13
9	75% DDT, 0.66 plus 15% parathion, 0.5	1	4
10	*Black Leaf 253*, 2.5	1	3
11	50% methoxychlor, 1 plus 15% parathion, 0.5	1	5
12	25% Q-137, 2 plus 15% parathion, 0.5	4	27
13	50% DDD, 1 plus 15% parathion, 0.5	2	13
14	Check	18	139
	L.S.D. (19:1)		10
	L.S.D. (99:1)		13

[1] Used 1.5 pints per 100 gallons.
[2] Used 1 pint per 100 gallons.

Table 9.—Codling moth control at Geneva, N. Y. in 2 tree plots, 1952.

Plot	Material and Quantity per 100 Gallons	Per Cent Wormy July 31	Worms per 100 Apples
1	25% Q-137, 4 lbs.	13	90
2	25% CS-708, 2 lbs.	3	11
3	25% CS-708, 4 lbs.	1	2
4	25% CS-708,[1] 2 lbs.	16	38
5	75% DDT, 1⅓ lbs. plus 20% TEPP, ¼ pt.	1	8
6	15% parathion, 2 lbs.	3	25
7	33% *Chlorthion*, 1 lb.	2	79
8	25% *NPD*, 2 lbs.	8	77
9	18.5% isodrin emuls., 2 pts.	27	219
10	18.5% endrin emuls., 2 pts.	30	180
11	Check	18	139

[1] Formulation made from purified product.

Table 10.—Codling moth control at Geneva, N. Y., 1953.

Plot	Material and Pounds per 100 Gallons	Per Cent Wormy Aug. 3	Worms per 100 Apples
1	75% DDT, 1.33	1	2
2	75% DDT, 0.66	2	6
3	50% methoxychlor, 2	1	11
4	25% *Chlorthion*, 2	3	40
5	Lead arsenate, 3 plus lime, 3 plus 25% malathion, 0.5	13	84
6	75% DDT, 0.66 plus 15% parathion, 0.5	1	4
7	*Black Leaf 253*, 2.5	1	8
8	75% DDT, 0.66 plus 40% TEPP[1]	2	5
9	75% DDT, 0.66 plus 25% malathion, 0.5	1	5
10	75% DDT, 0.66 plus 15% Aramite, 0.75	2	8
11	75% DDT, 0.66 plus 25% *Chlorobenzilate*, 0.5	2	11
12	75% DDT, 0.66 plus 50% *Ovotran*, 0.5	1	11
13	75% DDT, 0.66 plus 25% demeton[1]	2	14
14	Check	50	297
	L.S.D. (19:1)		18
	L.S.D. (99:1)		24

[1] Used ¼ pint per 100 gallons.

did not make effective mixtures. None of the phosphates gave good seasonal control, again due to late entries. Malathion, however, was not entirely effective early in the season as indicated by the 3 and 4 per cent wormy fruit in the first brood count.

As shown in table 9, Q-137 used alone was weak against codling moth. Also poor or ineffective were *Chlorthion*, *NPD*, isodrin and endrin. CS-708 as the regular commercial product was equal to DDT but when purified it was inferior.

1953 Tests.—Although the temperature records do not show more than a slightly above normal season, temperatures during the last half of June and the first of July were very high. This was during the peak of first brood larval activity and made control difficult. Some growers failed to get adequate control with DDT applied in the usual way. For the season, however, most growers were successful with the regular DDT program. In the experimental orchards there was an exceptionally heavy population in check trees. Treatments in the larger plots were applied to 3 McIntosh and 3 Cortland trees. The five cover sprays were applied on June 15, 29, July 13, 30 and August 12. The results are shown in tables 10 and 11.

DDT at regular strength gave excellent control and good control at half strength. Methoxychlor appeared slightly weaker than DDT but the difference was not significant. Analysis of variance for just those plots containing DDT (i.e., omitting plots 4, 5 and 14) show no significant differences between treatments. There is no indication, then, that the addition of any of the commonly used acaricides appreciably affected codling moth control. *Chlorthion* and lead arsenate plus malathion were not satisfactory. Three pounds of lime was used with the lead mixture and may have reduced the value of the malathion.

In the small plot tests, the special formulations of DDD and CS-708 at the dosages used performed about as expected. *Strobane* was not effective during any part of the season. *Ryanexcel 96-3* demonstrated some toxicity but was not effective as used. The methyl analog of demeton had some value in codling moth control. Malathion wettable powder was more effective than in previous tests, probably because there was little late season activity in 1953. The emulsion formula-

Table 11.—Codling moth control at Geneva, N. Y., in two-tree plots, 1952.

Plot	Material and Quantity per 100 Gallons	Per Cent Wormy Aug. 3	Worms per 100 Apples
1	*Black Leaf* 25% TDE, 2 lbs.	23	91
2	*Black Leaf* 25% CS-708, 2 lbs.	2	18
3	50% *Strobane*, 2 lbs.	21	131
4	*Ryanexcel 96-3*, 3 lbs.	12	96
5	50% *Bayer 21/116* emuls., ½ pt.	3	65
6	25% malathion, 2 lbs.	3	4
7	85% malathion emuls., ½ pt.	6	65
8	50% malathion emuls., ½ pt.	10	68
9	25% Diazinon, 2 lbs.	1	2
10	25% *4389*, 2 lbs.	1	2
11	75% DDT, ⅔ lb. plus 25% *Isolan* emuls., ¼ pt.	3	8
12	75% DDT, ⅔ lb. plus 25% *Nitrox* emuls., ¼ pt.	1	15
	Check	50	297

tions of malathion did not hold and were showing to poor advantage at the end of first brood. Diazinon and *4389* performed exceptionally well but they may have the same weakness as the other phosphates under certain conditions.

PHYTOTOXICITY OF EXPERIMENTAL MATERIALS.—The primary purpose of this paper is to present results of codling moth control. However, records have been kept on phytotoxicity and a brief summary is presented here.

Many of the phosphate insecticides caused injury to the McIntosh and Cortland varieties. EPN in repeated applications caused both foliage and fruit injury at ¼ pound per 100 gallons. Parathion injured young leaves and produced a trace of fruit spotting at ½ pound of 15 per cent wettable powder or its equivalent per 100 gallons. At 1 pound considerable fruit injury occurred under conditions favorable for injury. Certain activated carbons prevented fruit and foliage injury (Glass 1950) but no corrective for EPN has been found. Malathion wettable powder has not been injurious to the three apple varieties used in this test but the emulsifiable formulation caused slight spotting of McIntosh and Cortland fruits in 1952. Metacide caused injury in about the same manner as parathion. *Potasan* injured the fruit of all three apple varieties used in these tests. *Chlorthion* did not injure in 1952 but caused severe spotting to McIntosh and Cortland apples and roughened the finish of Greenings in 1953. *NPD* caused a trace of spotting and some roughening of McIntosh fruit. The early 32 per cent demeton emulsifiable severely injured McIntosh fruit at 1 quart per 100 gallons in 1950. The next year ½ pint of 50 per cent emulsifiable caused slight injury. The wettable powder did not. Subsequent trials at lower dosages have not been injurious. Off-flavor was imparted to the fruit in 1950 and 1951 but not in any test since then. The methyl analog (*Bayer 21/116*) was not harmful.

Of the other insecticides that were tested the following caused injury: *Arathan* injured foliage and about 50 per cent of the foliage was off the McIntosh trees by mid-August. CS-708 and one of its components have injured fruit on some occasions and not on others. In 1949 the CS645A emulsifiable did not injure McIntosh fruits but did in 1950 when used as a wettable powder. The 1950 CS-708 wettable powder caused an occasional spot on apples whereas the 1951 powder caused injury to 56 per cent of McIntosh and 77 per cent of Cortland apples. Many of the apples were very severely injured. In 1952, the 1951 formulation again caused severe injury whereas the 1952 product did not. There is then an indication that the difficulty was due to an impurity or break-down chemical found in certain formulations and not in others. The manufacturer found considerable instability in certain formulations.

DISCUSSION.—The problem of summer pest control on apples is complex due to the fact that several species are involved. The major ones in New York at present are codling moth, apple maggot, red-banded leaf roller, mites and aphids. Any material that has no, or inferior, toxicity to any one of these has to be supplemented with additional pesticides in one or more sprays. DDT is outstanding against codling moth, good against apple maggot at 10 to 12 day spray intervals but poor or ineffective against the others. It remains in the summer spray schedule primarily for codling moth control. If the codling moth becomes resistant to DDT it will likely be omitted from the summer program. For the time being, however, it remains the basic control agent for the cover sprays and new chemicals must be measured against it as a standard with regard to control, cost, phytotoxicity, hazard of handling, and compatibility. During this study certain materials have been tested which under the conditions of the experimental work or under commercial operation have been equal to DDT for codling moth control, yet have failed to meet one or more of the other requirements. No attempt is made here, however, to evaluate these other limitations for the materials tested.

The technic used in these codling moth experiments gave all treatments a severe test. The insect population was purposely maintained at a high level. Second brood activity in particular was much greater than is normally encountered in commercial plantings. Yet under these rigorous conditions DDT performed very well. Its superiority over most other insecticides was repeatedly demonstrated. Thus, 2 pounds of 50 per cent DDT per 100

gallons applied in five cover sprays at 2-week intervals has been considered the standard. Only in 1949 did this program weaken a little and then uneven spacing of sprays may have been a factor.

Among the chlorinated hydrocarbons tested, CS-708 was the only one that equalled DDT for codling moth control on the basis of equal dosage. Methoxychlor was almost as good and certainly could be successfully substituted for DDT. DDD was found to be less effective but still somewhat more efficient than lead arsenate. Q-137 alone would not be satisfactory for most conditions.

The phosphate group generally has considerable value against the codling moth. Of these parathion was most widely tested and control *throughout the spray period* has consistently been equal or superior to that obtained with DDT. However, late worm activity may cause considerable loss. In 1950 two grower tests were made comparing DDT and parathion. In one orchard control with both materials using four cover sprays was excellent. In the other orchard, 3 parathion sprays allowed 6 worms per 100 apples whereas 4 sprays reduced the infestation to 1 as compared to 0.1 for four DDT sprays. The evidence is that parathion could be used successfully against codling moth in New York. Several tests show that parathion can be used with DDT, methoxychlor or lead arsenate. Under New York conditions there has been no need to supplement DDT for codling moth control. The subject of combinations has been reported on by Kriner *et al.* (1952). The toxicity of parathion to moths, eggs and larvae even after entrance into the apple has been reported by D. W. Hamilton *et al.* (1954)[2] and by Soenen & Wetswinkel (1953). Activated carbon had a tendency to improve control but it leaves too much black residue on the fruit if used after the second cover spray.

Of the other phosphates, EPN was about equal to parathion, malathion was generally not as effective but still considerably superior to lead arsenate. Diazinon and *4389* appeared promising in preliminary tests.

Among the other materials tested, none appeared promising at the dosage levels used. *Ryanexcel 96-3* at 3 pounds per 100 gallons was not satisfactory. Aldrin, endrin and isodrin were found to be ineffective. The nonphosphate acaricides had little or no value.

SUMMARY.—The results of field trials with various insecticides against codling moth are presented. The tests were made from 1948 through 1953 in two experimental orchards at Geneva, N. Y. where heavy populations were maintained by leaving half to two-thirds the trees untreated with insecticides as checks. A five-cover spray program was used each year timed for three applications against first brood and two against second.

DDT at the rate of 2 pounds of 50 per cent wettable powder or the equivalent of 75 per cent formulation was the standard and gave consistently excellent control with the exception of 1949, when it was better than other materials tested. Lead arsenate gave relatively poor control in most tests. CS-708 was about equal to DDT whereas methoxychlor was slightly less effective. DDD was still less effective but superior to lead arsenate. Q-137 was not satisfactory in these tests.

Generally the phosphate insecticides were toxic to the codling moth but in a full season program were inferior to DDT for the prevention of late season entries. Parathion was one of the most effective of this group followed by EPN and malathion. Results of combinations of phosphates with DDT, DDD, methoxychlor and lead arsenate are given. Diazinon and *4389* were excellent in one season's test.

Results with numerous other chemicals are presented. In general none showed much promise. DDT remains the best control agent for codling moth in New York. There is little likelihood that any of the presently available materials will take its place as long as resistance to DDT does not develop.

[2] Hamilton, D. W., S. A. Summerland, and J. E. Fahey. 1954. Codling moth control experiments 1950–1953. Unpublished manuscript.

LITERATURE CITED

Glass, E. H. 1950. Parathion injury to apple foliage and fruit. JOUR. ECON. ENT. **43**(2): 146–51.

Kriner, E. R., J. E. Dewey and L. B. Norton. 1952. Orchard evaluation of DDT formulations and DDT-acaricide combinations. JOUR. ECON. ENT. **45**(6): 957–65.

Newcomer, E. J., and F. P. Dean. 1943. Experimental methods in making orchard tests for codling moth control in the west. U.S.D.A. **ET-215**.

Soenen, I. A., and G. Wetswinkel. 1953. Experiments on the control of the codling moth (*Laspeyresia pomonella* L.) carried out in 1952. Hofchen-Briefe **6**(3): 142–57.

Dichloropropane-dichloropropene Mixtures of Different Composition as Soil Fumigants in Pineapple Land[1]

WALTER CARTER, *Pineapple Research Institute, Honolulu, Hawaii*

The purpose of this paper is to present data on the use of mixtures of dichloropropane and dichloropropene which differed materially in proportionate composition from the commercial mixture known as D-D(Carter 1945).

THE FORMULATIONS.—Series I. A basic mixture composed by weight as follows: 1,3-dichloropropene, 80 per cent; other dichloropropenes, 2 per cent; dichloropropanes, 5 per cent; trichloropropenes, 6–7 per cent; and trichloropropanes, 6–7 per cent. Using this material as a base, four formulations were derived for actual field application. These were: (1) the basic material as supplied, 100 per cent; (2) the basic material diluted with an equal part by volume of 1,2-dichloropropane (propylene dichloride of trade); (3) the basic material diluted with an equal part by volume of Standard Oil Company Paint Thinner No. 200; (4) the basic material diluted with an equal part by volume of Diesel oil.

Series II. A series of four mixtures whose approximate composition is shown in table 1.

Series III. Four chlorinated propane-propene mixtures composed as follows:

Table 1.—Percentage composition by weight of four different chlorinated propane-propene mixtures.

COMPOUND	MIXTURE A	B	C	D
Monochloropropene	0.5	—	—	—
Monochloropropane	0.5	—	—	—
Dichloropropene	11.5	3.7	—	23.5
Dichloropropane	25.7	12.6	4.0	
1,3-dichloropropene	36.5	30.6	4.0	22.0
Trichloropropene	6.3	18.5	20.0	30.6
Trichloropropane	6.4	17.3	10.0	
Tetrachloropropene	6.3	8.6	—	—
Tetrachloropropane	6.3	8.7	—	—
Tetra and higher			60.0	23.7

Table 2.—Average fruit weight (lbs.) following soil fumigation with formulations derived from a mixture containing 80% 1,3-dichloropropene (Series I) compared with D-D mixture at three dosage levels.

FORMULATION	200 LBS./A. Plant Crop	200 LBS./A. Ratoon Crop	300 LBS./A. Plant Crop	300 LBS./A. Ratoon Crop	400 LBS./A. Plant Crop	400 LBS./A. Ratoon Crop
1: 80% 1,3	4.31	3.28	4.47	3.17	4.40	3.39
2: 40% 1,3	4.24	3.33	4.38	3.29	4.20	3.06
3: 40% 1,3	4.02	3.27	4.14	3.16	4.37	3.25
4: 40% 1,3	4.02	3.12	4.05	3.05	4.13	3.31
D-D: 50% 1,3	4.07	3.17	4.38	3.31	4.54	3.52

Untreated checks: Plant crop 3.70; ratoon crop 3.00.
Differences necessary for significance at P = .05, 0.42; P = .01, 0.55 for plant crop treatments.
Differences not significant for ratoon crop.

(1) 1,3-dichloropropene, 90 per cent by weight with the low boiling point isomer (104.3° C.) predominating; (2) 1,3-dichloropropene 65 per cent, the remainder being largely 1,2-dichloropropane, by weight; (3) an intermediate mixture whose approximate composition was 1,3-dichloropropene, 25 per cent; 2,3-dichloropropene, 13 per cent; polychloropropenes, 12 per cent; 2,2-dichloropropane, 5 per cent, remainder (45 per cent), mostly 1,2-dichloropropane, by weight; (4) a crude product including 1,3-dichloropropene, 40 per cent and other propenes, 33 per cent by weight.

FIELD TESTING.—All the tests herein, with one exception, were conducted in the field under normal plantation conditions. Application of the fumigants was by hand operated injectors, the injections being made through the mulch paper at the planting sites, approximately 12 inches apart, in plots 10 feet long containing 20 plants each with three replications. All the fruits were weighed. Field 1 of table 3 was an exception. In that case the fumigants were broadcast mechanically in large

[1] Published with the approval of the Director as Technical Paper No. 228 of the Pineapple Research Institute, Honolulu, Hawaii.

Table 3.—Average fruit weights (lbs.) from two different fields following soil fumigation with formulations derived from a mixture containing 80% 1,3-dichloropropene (Series I) compared with D-D mixture, all at 400 lbs./A.

Formulation	Field 1		Field 2	
	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop
1: 80% 1,3	5.26	4.30	4.66	2.75
2: 40% 1,3	5.05	3.96	4.43	2.48
3: 40% 1,3	4.95	3.59	4.44	2.36
4: 40% 1,3	5.04	3.55	4.39	2.27
D-D: 50% 1,3	5.42	4.06	4.69	2.97
Untreated check	—	—	3.61	2.27
L.S.D. P=.05	0.29	n.s.	0.22	0.22
P=.01	0.40	n.s.	0.30	0.29

plots and sampling was done by weighing all the fruits in 150 feet of bed in each of six replications.

RESULTS.—These are shown in tables 2 to 7. In order to permit easy comparison of results in relation to 1,3-dichloropropene content, this has been added to the formulation column in each table.

DISCUSSION.—Results of tests with Series I are available for both plant crop and ratoon experiments conducted in seven different fields on three islands, at dosages of 200 to 400 pounds per acre. In three of these experiments, fruit yields in plant crop were not significantly increased over an untreated check but in each of these experiments the ratoon crops showed a significant gain over the untreated

Table 4.—Average fruit weights (lbs.) in four different fields following soil fumigation with formulations derived from a mixture containing 80% 1,3-dichloropropene (Series I) compared with D-D mixture, all at 300 lbs/A.

Formulation	Field 1		Field 2		Field 3		Field 4	
	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop
1: 80% 1,3	4.64	2.57	5.12	3.67	3.75	2.97	4.72	4.26
2: 40% 1,3	4.52	2.71	5.16	3.59	3.61	2.85	4.79	4.39
3: 40% 1,3	4.60	2.83	5.07	3.67	3.44	2.85	4.76	4.42
4: 40% 1,3	4.55	2.61	5.16	3.68	3.62	2.92	4.71	4.42
D-D: 50% 1,3	4.66	2.76	5.31	3.61	3.57	2.97	4.83	4.16
Untreated check	3.75	2.65	4.90	2.52	3.50	2.72	4.50	3.59
L.S.D. P=.05	0.18	n.s.	n.s.	0.24	n.s.	0.21	n.s.	0.27
	0.25	n.s.	n.s.	0.32	n.s.	0.28	n.s.	0.37

Table 5.—Average fruit weights following soil fumigation with 3 formulations of Series II compared with D-D mixture, all at three dosage levels.

Formulation	200 Lbs./A.		300 Lbs./A.		400 Lbs./A.	
	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop	Plant Crop	Ratoon Crop
A: 36.5% 1,3	3.49	3.06	3.72	2.80	3.98	3.11
C: 4.6% 1,3	3.06	2.86	3.32	3.05	3.41	3.08
D: 22.0% 1,3	3.30	2.85	3.59	3.11	3.89	3.12
D-D: 50% 1,3	3.63	3.25	3.63	3.02	—	—

Untreated checks: Plant crop, 2.77; ratoon crop, 3.18.
Differences necessary for significance at P=.05, 0.40; P=.01, 0.53, for plant crop treatments.
Differences not significant for ratoon crop.

Table 6.—Test with formulation B of Series II (30.6% 1,3) compared with D-D mixture (50% 1,3) at varying dosages.

Treatment and Pounds per Acre		Plant Crop	Ratoon Crop
Formulation B	200	3.78	3.10
	B 300	4.00	3.22
	B 400	3.91	3.24
D-D	200	3.30	3.13
	300	3.77	3.22
Untreated check		2.56	3.35

Table 7.—Comparison of four separate formulations varying in 1,3-dichloropropene content from 25 to 90 per cent (Series III) applied with and without a diluent.

Fumigant Dosage Lbs./A. Rubber Solvent Added by Volume	Field 1			Field 2	
	100 3 parts	200 None	200 1 part	200 None	200 None
Formulation 1: 90% 1,3					
Plant Crop	3.98	4.40	4.61	3.79	4.16
Ratoon Crop	3.48	3.76	3.83	3.17	3.33
Formulation 2: 65% 1,3					
Plant Crop	3.45	4.23	4.45	3.88	3.77
Ratoon Crop	3.39	3.65	3.57	3.03	3.31
Formulation 3: 25% 1,3					
Plant Crop	2.84	3.62	3.47	3.58	3.69
Ratoon crop	3.27	3.40	3.03	3.00	2.96
Formulation 4: 40% 1,3					
Plant Crop	3.48	4.04	3.98	3.69	3.96
Ratoon Crop	3.34	3.37	3.53	3.25	3.11
D-D: 50% 1, 3					
Plant Crop	3.48	4.42	4.18	3.67	—
Ratoon crop	3.40	3.57	3.37	3.20	—
Untreated checks					
Plant crop		2.66		2.75	
Ratoon crop		3.27		3.22	

Differences required for significance:	P=.05	P=.01
Plant crop (Field 1)	0.35	0.46
Plant crop (Field 2)	0.48	n.s.
Ratoon crop (Field 1)	0.30	0.40
Ratoon crop (Field 2)	0.20	0.28

check. Two experiments showing significance in plant crop showed none in ratoon. This is typical of soil fumigation experiments in pineapple land, significant gains occurring sometimes in plant crop, sometimes in ratoon, and sometimes in both crops.

In table 2, where three dosages are compared, all four formulations as well as D-D show significantly greater yields than the untreated check in plant crop. There was no significant difference between yields from the treatments but a trend in favor of the formulations containing the more active diluents. In table 3, which compares the formulations of Series I at the 400-pound dosage, differences reach significance but without correlation with 1,3-dichloropropene content.

In the four experiments using a dosage of 300 pounds per acre (Table 4) the significant differences are found only between the untreated check and the fumigated plots with none between the four formulations and the standard D-D.

Series II is of particular interest because of the detailed analysis available and for the low percentages of 1,3-dichloropropene.

Formulation C in Table 5 definitely reduced yields in plant crop when compared with A, D, and D-D. This was due to phytotoxicity which expressed itself as yellowed slow-growing plants. This did not carry over to ratoon, however, and might have been avoided by allowing more time lapse between treatment and planting. Since newly papered pineapple fields are vulnerable to wind and wash, any material requiring a time lapse of more than 5 or 6 days would be difficult to include in field practice. Formulations A, B and D, however, in Series II (Tables 5 and 6) were essentially the equal of D-D at equivalent dosages for plant crop, the slightly inferior position of D being accounted for by the relatively higher percentage of the polychlor compounds present.

Series III included formulations applied with and without an inactive diluent. Formulation 3 of this Series with its low 1,3-dichloropropene content is indicated as inadequate by comparison with others in the Series but between Formulations 1, 2, 4 and D-D there is insufficient difference to justify a formulation based primarily on its 1,3-dichloropropene content.

ACKNOWLEDGEMENTS.—Series I and II were supplied by the Dow Chemical Company, Series III by Mathieson Alkali Company.

The assistance of C. T. Schmidt and K. Ito during the course of this study is gratefully acknowledged.

SUMMARY.—Three series of formulations of chlorinated propane-propene mixtures have been tested in comparison with the standard commercial compound known as D-D mixture. Based on growth response as measured by fruit weight, it is indicated that 1,3-dichloropropene is an essential component of mixtures of chlorinated propanes and propenes for soil fumigation but not necessarily in specific proportions.

Mixtures comprising compounds in the boiling range of ca 70° to 140°C. with an approximate minimum of 30 per cent 1,3-dichloropropene should prove interesting experimentally. They should contain a minimum of the higher boiling point compounds as contaminants on account of their phytotoxicity.

LITERATURE CITED

Carter, W. 1945. Soil treatments with special reference to fumigation with D-D mixture. JOUR. ECON. ENT. 38(1): 35–44.

A Laboratory Apparatus for Determining Repellency of Pyrethrum When Applied to Grain

HAMILTON LAUDANI and G. R. SWANK, *Stored-Product Insects Section, Agr. Market. Serv., U.S.D.A.*[1]

The belief generally exists that the protection derived from pyrethrum dusts applied to grain or pyrethrum applied in clay coatings to paper bags or cartons results largely from the toxic action of this insecticide. Contrary to this belief, unpublished data obtained in experiments with coated paper at the Savannah, Ga., laboratory indicate that the usual application rates are too low to cause mortality after the first few days, but that there is a definite and long-lasting repellency. In laboratory tests there were fewer adult flour beetles (*Tribolium* spp.) on treated paper than on untreated paper long after the treated paper had ceased to produce any mortality or knockdown.

Although tests had been designed at this laboratory to demonstrate this action with treated kraft paper, there was no known method to determine whether the same action prevailed with grains treated with pyrethrum dusts or sprays. An apparatus developed for determining the repellency of pyrethrum when applied to grain is described in this paper. Experimental data are given to illustrate the use to which this apparatus can be put. Although the insecticide residue on the grain is expressed in terms of parts per million of pyrethrins, a synergized formula was used which contained pyrethrins and piperonyl butoxide in 1–10 ratio.

Loschiavo (1952) reported an apparatus for determining food preferences of stored-grain insects that had many features which could be used in an apparatus to demonstrate the repellency of pyrethrum residues on grain. His apparatus consisted of a circular wheel divided into 12 sectors by removable partitions which extended only as high as a common central platform. The sectors were filled with the various foods to be tested. The insects were introduced through a tube passing through a hole in an inverted petri dish onto the central platform, where they were retained until they had regained their normal composure. By raising the tube, which passed through the cover of the whole test area, the insects were released in the dark with little disturbance. They were then able to choose the food material of their preference. After a lapse of 48 hours the foods were removed, and the number of insects in each kind of food was counted.

FIG. 1.—View of the apparatus designed and constructed at the Savannah laboratory to determine the repellency of pyrethrum when applied to grain or seeds. The apparatus is a modification of one described by Loschiavo.

A modification of the Loschiavo apparatus was designed, and a working model was constructed of plywood and sheet metal.

DESCRIPTION OF APPARATUS.—The apparatus is shown in figure 1. It consists of a circular platform 20 inches in diameter (A) having a 2-inch metal rim. The platform has 12 holes (C) equidistantly spaced along the outer edge. The diameter of the holes (3-7/16 inches) is exactly that of ½-pint paper cups (B), which are used as containers for the treated grain. The cover (G) is slightly larger than the platform and has a 1-inch metal rim (H) around the edge and a rubber gasket (I) on the inner surface along the periphery. Like the Loschiavo apparatus, the cover has a hole in the center through which extends a copper tube (J) ½ inch in diameter and 8 inches in length. An inverted metal pan (K), 5-½ inches in diameter with a rim ¾ inch high, is attached to the lower end of the tube. The cover is held tightly to the platform when in use by clasps (L) made of spring steel.

The base of the apparatus is a plywood disk (E) 21 inches in diameter. The platform is supported above this base on a

[1] The authors wish to acknowledge the aid of R. H. Guy in conducting the biological tests.

single shaft which permits the platform to rotate. There is sufficient space between the base and the platform for the paper cups to clear as the platform is turned. By rotating the platform the cups can be removed from the bottom side through a hole (F) cut for this purpose in the disk which serves as the base.

The number of treatments or replications that can be run at one time are 1, 2, 3, or 5 treated materials and an untreated check with 6, 4, 3, or 2 replications, respectively.

TECHNIQUE.—The cups were first filled with the treated grain to be tested or with the untreated grain (check) and were then placed in the holes so that the rims were level with the platform. The cover was then clamped to the platform, and the tube was pushed down through the top so that the edge of the attached pan rested on the platform. The insects were introduced through the tube and allowed to rest under the pan for a period of time to regain their composure after which the insects were liberated by raising the pan. At the end of the exposure period, the cups were removed and covers placed over them to retain the insects until the counts could be made. The number of insects found in each cup was recorded, and the percentage of the total insects present in the cups for each treatment calculated.

ILLUSTRATIVE DATA.—A series of tests was conducted to determine whether flour beetles would be repelled by corn with residues of 0.25 and 0.37 p.p.m. pyrethrins as determined by chemical analysis. Cups in positions number 1, 4, 7, and 10 were filled with untreated corn. Those in number 2, 5, 8 and 11 were filled with corn which had been treated with pyrethrum in an oil emulsion at the rate of 0.25 p.p.m. of pyrethrins. The corn in cups 3, 6, 9, and 12 had been treated with pyrethrum dust at the rate of 0.37 p.p.m. of pyrethrins. This arrangement, which was generally used, allowed four replications of each treatment.

To illustrate a typical distribution of flour beetles in the cups, a test made early in this series is selected. In this test 250 adult flour beetles, 5 to 10 days old, were introduced into the appratus and, after a 30-minute rest period, were given 3 hours in which to enter the cups. At the end of the exposure, some of the insects were still on the platform or on the inside of the cover, but only those in the cups were counted.

Table 1.—Number of adult flour beetles per replicate present in treated and untreated corn after a 3-hour exposure.

Pyrethrins Present, P.P.M.	Replicates				Average of 4 Replications	Per Cent of Total* in All Cups
	1	2	3	4		
None (check)	44	37	51	28	40.0	75.2
0.25	13	14	5	7	9.8	18.2
0.37	3	6	3	2	3.5	6.6

The distribution of the adult flour beetles in the two lots of treated corn and in the untreated corn is shown in table 1. These figures definitely show that the flour beetles not only were repelled by treated corn but that they detected the difference between the two concentrations of pyrethrins used on the corn.

To determine whether the results could be duplicated with the apparatus, five tests were conducted with the same lots of corn. Various numbers of adult flour beetles were used in overnight exposures of 17 hours. A different lot of insects was used in each test. They were given a 30-minute rest period before being liberated. Special precautions were taken to avoid cross contamination of the corn, because the same corn was used in all five tests.

The results of these exposures (Table 2) showed definite trends in the same direction as in the first series of tests. Although there was considerable variation between the several exposures, the apparatus and test techniques appear to be sufficiently sensitive to insure reliability of results.

To determine whether a mixed insect population could be used in a single run, a test was conducted in which three species of insects were used simultaneously. The saw-toothed grain beetle, *Oryzaephi-*

Table 2.—The distribution of flour beetles in treated and untreated corn after exposure for 17 hours.

Test Number	Number of Insects	Percentage in Each Group		
		Untreated Check	0.25 p.p.m. Pyrethrins	0.37 p.p.m. Pyrethrins
28	134	92.5	7.5	0
28a	137	80.6	14.7	4.7
28b	168	74.4	22.4	3.2
36a	76	82.9	9.2	7.9
36c	387	92.2	5.0	2.8
Average	—	84.5	11.8	3.7

Table 3.—The distribution of three species of insects in treated and untreated wheat after exposure for 17 hours.

Test Insect	Number of Insects	Percentage in Each Group		
		Untreated Check	0.1 p.p.m. Pyrethrins	0.3 p.p.m. Pyrethrins
Saw-toothed grain beetle	151	52.1	29.6	18.3
Lesser grain borer	149	69.1	20.8	10.1
Siamese grain beetle	111	73.0	18.0	9.0

lus surinamensis (L.), the lesser grain borer, *Rhyzopertha dominica* (F.), and the Siamese grain beetle, *Lophocateres pusillus* Klug., were placed in the apparatus at the same time and exposed for 17 hours. For this test pyrethrum dust was applied to two lots of wheat at rates calculated to give 0.1 and 0.3 p.p.m. of pyrethrins. Untreated wheat was used as the check. The results are given in table 3. Although three species were present in the test apparatus, the repellency of the treated grain to each follows the same trends as in tables 1 and 2 where only a single species was present.

In all the tests with more than one species it was found that each was repelled to a different degree by the same level of residue. To illustrate these differences, data have been selected from two series of tests in which seven species of insects were used. In one series, pyrethrum dust was applied to whole black pepper at rates calculated to give 0.1 p.p.m. and 0.3 p.p.m. of pyrethrins, and in the other 0.5 and 1.0 p.p.m. of pyrethrins. Untreated pepper was used as the check in both series. The seven species of insects used were adults of the flour beetles, the saw-toothed grain beetle, the cigarette beetle, *Lasioderma serricorne* (F.), the siamese grain beetle, the rice weevil, *Sitophilus oryzae* (L.), the lesser grain borer, and larvae of the black carpet beetle, *Attagenus piceus* (Oliv.).

As shown in table 4, each of the seven species displayed a different degree of reaction to the treated pepper, a demonstration that repellency of a given treatment varies according to the species. These results show trends similar to those in table 3. The use of more than one species at one time should be investigated further. This particular phase of study is quite important because, if a number of species can be used simultaneously, the time required to evaluate a number of treatments would be reduced substantially.

Discussion.—In adapting the Loschiavo apparatus from its original use of determining the food preference of certain insects to testing the repellency of insecticide-treated grains, certain changes were necessary. The major change was the elimination of the compartments for holding the media and substituting removable cups for the purpose. The following advantages were derived by this simple change: (1) a neutral area was provided around each cup which the insects could use for reaching any medium without having to cross another while in the process; (2) cross contamination of the media was lessened considerably by the space present between the samples; (3) the media were placed in and removed from the apparatus without spilling into adjacent samples; and (4) the cups containing the material under test were removed quickly and covered, thus retaining all of the insects present in the cups until the insect counts were made. Furthermore, the changes made increased the versatility of the apparatus as well as speeded and simplified

Table 4.—Percentage insects in whole black pepper with different amounts of pyrethrins.

Test Insect	Series I			Series II		
	Untreated Check	0.1 p.p.m. Pyrethrins	0.3 p.p.m. Pyrethrins	Untreated Check	0.5 p.p.m. Pyrethrins	1.0 p.p.m. Pyrethrins
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Flour beetle	75.4	14.1	10.5	66.3	14.6	19.1
Saw-toothed grain beetle	53.6	25.2	21.2	53.6	29.0	17.4
Cigarette beetle	39.9	32.0	28.1	50.5	28.2	21.3
Siamese grain beetle	56.2	21.0	22.8	58.3	24.3	17.4
Rice weevil	37.4	32.0	30.6	65.1	23.7	11.2
Lesser grain borer	39.9	40.0	20.1	55.2	21.3	23.5
Black carpet beetle larvae	35.3	31.6	33.1	38.7	27.6	33.7

its operation. At one time, either 1, 2, 3, or 5 untreated materials and the untreated check could be tested. The apparatus appeared to be very effective for determining the repellency of treated grains to insects.

Once the treated grain and the test insects are available, only a few minutes are required to get the apparatus set up and in operation. No further attention is required until the end of the exposure period. The tests conducted have shown that the results obtained in the repellency tests are significantly the same with exposure periods of from 3 to 24 hours. Therefore, the exposure period can be varied to suit the workload on hand. The technique used is so simple that no special skill is required for its operation.

The results of the exploratory tests with this apparatus using the adult flour beetles definitely showed that the insects were repelled by treated corn, and that they detected differences between 0.1 and 0.3 p.p.m. and between 0.25 and 0.37 p.p.m. of pyrethrins. It is interesting to note, however, that the number of adult flour beetles found in pepper treated with 0.5 and 1.0 p.p.m. pyrethrins was greater than in pepper treated with 0.3 p.p.m. but that many of these were dead or moribund. This indicates that repellency studies should be conducted only with sublethal dosages.

SUMMARY.—An apparatus was developed for testing the repellency of insecticide-treated grains to stored-product insects. This apparatus had 12 cups which held samples of treated and untreated grains in an enclosure in which the insects were liberated. The insects entered the sample they selected, and the relative numbers present in the treated and untreated samples indicated the degree of repellency.

Data are presented to illustrate the effectiveness of the apparatus to determine the repellency of treated grains to certain stored-product insects. These data showed that adult flour beetles were repelled by treated corn, and that they detected the differences between 0.1 and 0.3 and between 0.25 and 0.37 p.p.m. of pyrethrins

LITERATURE CITED

Loschiavo, S. R. 1952. A study of some food preference of *Tribolium confusum* Duv. Cereal Chem. 29(2): 91–107.

The Effects of Red, White, and South American Cedar Chests on the Various Stages of the Webbing Clothes Moth and the Black Carpet Beetle

HAMILTON LAUDANI, and P. H. CLARK, *U.S.D.A.*[1]

References to the toxicity of cedar wood to fabric insects and to the protection of woolens against insect damage when stored in chests made of this wood date back to 1682 (Back & Rabak 1922). Since that time, studies on the insecticidal properties of wood and oils of red cedar (*Juniperus virginiana*) to fabric pests have been conducted by a number of investigators. The results of these studies generally have indicated that the younger larvae were adversely affected by the vapors emitted by the cedar wood, but that the older larvae and the other stages were unaffected (Back & Rabak 1922, Scott *et al.* 1918). Although some of these studies have been rather extensive, only sketchy data have been presented, and, as stated by Sweetman (1953), the possible protective value of cedar vapors in tight chests has not been fully shown.

At the request of the U. S. Federal Trade Commission, tests were started in 1947 at the Savannah, Ga., laboratory of the U. S. Department of Agriculture to determine the comparative toxicity and protective value of chests made of red cedar and white cedar (*Chamaecyparis thyoides*). Preliminary tests with wood of the South

[1] Stored-Product Insects Section, Agricultural Marketing Service and Entomology Research Branch, Agricultural Research Service, respectively. These studies were carried on while both authors were members of the former Bureau of Entomology and Plant Quarantine.

Table 1.—Per cent hatching of eggs of the black carpet beetle and the webbing clothes moth after exposure in cedar chests.

Type of Chest	Age of Chest	Eggs Laid in Chest		Eggs Introduced	
		Beetles	Moths	Beetles	Moths
	Months	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Red Cedar	16	11	35	15	74
White cedar A	16	19	56	24	77
White cedar B	8	24	56	29	85
South American	4	15	30	13	54
Pine (check)	—	64	82[1]	25	79

[1] Approximate figure, presence of live adults prevented an accurate count.

American cedar (*Cedrella odorata*) showed that this wood also emitted vapors which were toxic to fabric insects. Therefore, chests made of this wood were also included in the tests. During these rather extensive studies over a period of 3½ years, considerable information was obtained on the effects of these different cedar chests on the various stages of the black carpet beetle, *Attagenus piceus* (Oliv.), and the webbing clothes moth, *Tineola bisselliella* (Hummel). Since previous studies had indicated that the age of a chest was also a factor, each series of tests was repeated periodically to develop data on this point. Results of these studies are presented to supplement and strengthen previously published data on this subject.

MATERIALS AND METHODS.—The chests used in the tests were two of the red, six of the white, and two of the South American cedars. As checks, two white pine (*Pinus strobus*) chests were used. The average inside dimensions of all of the chests were 44½ by 16½ by 12 inches, and they were made of 1-inch stock dressed down to ¾ inch. The red and white cedar chests were made by commercial cedar chest manufacturers, the latter by two different firms, and these are designated as "A" and "B." The South American cedar and the pine chests were made by cabinet makers according to cedar chest specifications. The age of each chest was dated from the day received.

In all the tests, the insects were exposed in cages made of 6-ounce tin salve cans with 100-mesh wire cloth over a 1.5-inch square opening made in the top and bottom of each can. Each cage contained a 1-inch square of woolen cloth. The chests were approximately one-third filled with woolen material, and four cages were suspended in the free air space of the chests.

During the entire testing period, the chests were stored in a room having a constant temperature of 80° ± 2° F. and relative humidity of 60 ± 5 per cent.

All insects were from laboratory cultures reared under the same conditions as existed in the room in which the chests were stored while under test.

EFFECT ON EGGS.—To determine the effect of cedar vapors on the egg stage, approximately 100 one-day-old eggs of the carpet beetle and of the clothes moth were introduced in each chest. In separate cages, 40 newly emerged adults of each species were also introduced. The percentages of eggs which hatched of those introduced and of those oviposited by the adults in the chests are shown in table 1.

Viable eggs were laid in all the cedar chests by both species. However, a smaller percentage of eggs laid in the chests hatched in the cedar chests than in the pine (check) chests. About the same percentage of introduced eggs hatched in the cedar chests as in the pine chests, with the exception of the carpet beetle eggs in the red and South American cedar chests, and the clothes moth eggs in the South American cedar chests. Apparently the cedar chests had a limited effect on the viability of the eggs laid inside the chests, but little or no effect on introduced eggs.

EFFECT ON LARVAE.—Larvae of both insects were exposed inside the chests after various intervals of aging and the mortality was recorded. At the time they were introduced into the chests, the black carpet beetle larvae were 70 days old, and the webbing clothes moth larvae were 4 and 21 days old, representing newly hatched and mature larvae. The tests were conducted with 10 insects of each kind and age in each of four replications. The results of these tests are in tables 2 and 3.

The younger larvae of the clothes moth were much more susceptible to the cedar action than the older larvae; and the larvae of the clothes moth were more susceptible than those of the carpet beetle. As shown in table 2, the mortality of the 4-day-old clothes moth larvae was consistently higher than that of the 21-day-old larvae. In the tests started when the chests were 4 months old, the mortality obtained in a 1-month exposure was 32 to 77 per cent with the older clothes moth larvae but only 1 to 32 per cent with the carpet beetle larvae.

Table 2.—Per cent mortality of newly hatched and mature webbing clothes moth larvae after exposure of 1 month in cedar chests.

TYPE OF CHEST	AGE OF CHEST	4 DAYS OLD	21 DAYS OLD
	Months	*Per Cent*	*Per Cent*
Red cedar	4	93	74
	26	100	15
	40	—	25
White cedar A	4	52	32
	26	14	3
	40	—	21
White cedar B	4	94	59
	18	14	4
	30	—	15
South American	4	—	77
	16	13	0
	30	—	3
Pine (check)	16	0	0
	18	0	0
	26	0	0
	40	—	3

The South American cedar chests were the most effective against both species at the 4-month period, but lost practically all effectiveness after aging 16 months.

The red cedar chests were effective to a greater degree over a longer period than the others. They produced high mortality to carpet beetle larvae after 20 months of aging, but their effectiveness sharply declined after aging 24 months. These chests lost their effectiveness against 21-day-old clothes moth larvae after 26 months. The white cedar chests were not as toxic as the others, and their effectiveness declined after 16 to 20 months.

Table 3.—Per cent mortality of mature black carpet beetle larvae[1] after periods of exposure in cedar chests.

TYPE OF CHEST	AGE OF CHEST	MONTHS OF EXPOSURE					
		1	2	3	4	5	6
	Months	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Red cedar	4	3	16	62	97	99	99
	16	10	40	71	89	96	—
	20	2	4	21	54	87	98
	24	1	1	1	7	32	60
	30	0	0	0	0	0	0
White cedar A	4	4	15	25	63	72	91
	16	10	14	30	50	69	—
	20	1	1	2	7	12	32
	24	0	0	0	1	2	2
	30	0	0	0	0	0	0
White cedar B	4	1	2	7	24	48	—
	12	1	2	5	9	22	42
	16	0	1	1	2	3	4
	20	0	0	0	0	0	0
South American	4	32	62	83	89	98	—
	8	2	4	8	28	57	72
	16	3	3	4	5	5	5
	20	0	0	0	0	0	0
Pine (check)	8	3	3	4	5	7	10
	12	3	3	4	5	7	10
	16	0	0	0	0	0	0
	20	3	3	4	5	7	10
	24	0	0	0	0	0	0
	30	0	0	0	0	0	0

[1] Larvae were 70 days old when introduced.

Table 4.—Per cent larval and pupal mortality and per cent adult emergence obtained from black carpet beetles introduced into the chests as last-instar larvae.

TYPE OF CHEST	AGE OF CHEST	EXPOSURE PERIOD	LARVAL AND PUPAL MORTALITY	LARVAE TO REACH ADULT STAGE
	Months	*Weeks*	*Per Cent*	*Per Cent*
Red Cedar	20	4	0	0
		8	0	4
		12	16	32
		16	58	38
		20	62	38
White cedar A	20	4	0	2
		8	0	12
		12	2	58
		16	4	88
		20	4	90
		24	4	70
		28	6	90
		32	6	90
		36	6	90[1]
White cedar B	11	4	0	10
		8	0	14
		12	0	56
		16	2	70
		20	2	72
		24	2	72
		28	4	72
		32	8	72
		36	10	72[1]
South American	9	4	0	0
		8	2	20
		12	4	58
		16	4	70
		20	4	70
		24	6	70
		28	10	70
		32	16	70
		36	16	70[1]
Pine (check)	20	4	0	10
		8	2	40
		12	2	78
		16	2	78
		20	2	78
		24	2	78
		28	4	78
		32	8	78
		36	8	78[1]

[1] Unaccounted for individuals still in larval stage.

EFFECT ON PUPATION AND ADULT EMERGENCE.—Last-instar larvae of both species were placed in each chest and observations were made periodically on mortality, pupation, and adult emergence. The results of these tests are shown in tables 4 and 5. The red cedar chests were the only ones that produced any significant mortality to immature stages of the black carpet beetle (table 4). However, all of the insects which died were in the

Table 5.—Per cent larval and pupal mortality and per cent adult emergence obtained with clothes moths introduced into the chests as last-instar larvae.

Type of Chest	Age of Chest	Exposure Period	Larval Mortality	Pupal Mortality	Larvae to Reach Adult Stage
	Months	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Red cedar	26	2	8	0	4
		4	14	14	56
		6	14	14	72
White cedar A	26	2	8	0	0
		4	12	4	78
		6	14	8	78
White cedar B	17	2	5	0	2
		4	10	1	68
		6	16	4	80
South American	15	2	4	0	0
		4	6	0	82
		6	8	3	89
Pine (check)	26	2	16	0	4
		4	16	0	84
		6	16	0	84

larval stage, with the exception of one pupa. The percentages of adult emergence in the white and South American chests were not significantly less than those in the pine chests. The percentage of webbing clothes moth larvae which reached the adult stage was very high, ranging from 72 per cent in the red cedar chests to 89 per cent in the South American cedar chests (table 5). There appeared to be no significant difference in the percentage of adult emergence which occurred in the cedar and in the pine chests.

Table 6.—Time required to produce 100 per cent mortality of adult insects when exposed in cedar chests, and oviposition occurring during that period.

Type of Chest	Age of Chest (Months)	Adults Exposed		Exposure Producing Total Mortality (Days)	Eggs Laid per Female
		Males	Females		
Black carpet beetle					
Red cedar	16	36	38	26	9
White cedar A	16	40	40	28	11
White cedar B	8	40	40	25	9
South American	4	36	38	26	8
Pine (check)	—	40	40	26	12
Webbing clothes moth					
Red cedar	16	58	46	4	20
White cedar A	16	32	39	4	8
White cedar B	8	58	47	4	6
South American	4	54	44	4	9
Pine (check)	—	67	55	11	14[1]

[1] Approximate figure, presence of live adults prevented an accurate count.

EFFECTS ON ADULTS AND ON OVIPOSITION.—Newly emerged adults of both insects were exposed in the various cedar chests and observations were made on their mortality and on oviposition. The results of these tests are shown in table 6. The time required for 100 per cent mortality of the black carpet beetle adults exposed in the cedar chests was no shorter than that in the pine chests. With the clothes moth adults, it was considerably shorter in the cedar chests. The average number of eggs laid by the carpet beetles in the cedar chests was slightly lower than in the pine chests. With the exception of the red cedar chests, the average number of eggs deposited by the clothes moths in the cedar chests was less than in the checks. Since viable eggs of both species were present in all the chests, cedar vapors appeared to have had little or no effect on the reproductive functions of these insects.

SUMMARY.—Tests were conducted at Savannah, Ga., with chests of red, white, and South American cedar to determine their toxicity at various ages to all stages of the black carpet beetle, *Attagenus piceus* (Oliv.), and the webbing clothes moth, *Tineola bisselliella* (Hummel). White pine chests were used as checks.

All of the test cedar chests had an inhibiting effect on the hatching of eggs of both species laid in the chests but little or no effect on eggs introduced after oviposition.

The mortality of the younger larvae was much higher than that of mature larvae after exposure in the chests. The full-grown larvae of the webbing clothes moth were more susceptible than those of the black carpet beetle. Four-month old South American cedar chests were the most effective against both species, but they lost practically all effectiveness after aging 16 months. The red cedar chests were effective to a greater degree over a longer period than the others, but toxicity to carpet beetle larvae fell off sharply after aging 24 months. The white cedar chests were never as effective as the others, and toxicity to carpet beetle larvae declined after 16 to 20 months of aging.

Exposure of mature larvae had little or no effect on the pupation and adult emergence of either species. Exposure of black carpet beetle adults did not cause mortality in excess of that in the pine chests, and

did not significantly inhibit oviposition. Exposure of clothes moth adults resulted in some mortality, but adults mated and laid a considerable number of viable eggs.

LITERATURE CITED

Back, E. A., and R. Rabak. 1922. Red cedar chests as protectors against moth damage. U. S. Dept. Agr. Bul. 1051.

Scott, E. W., W. S. Abbott, and J. E. Dudley, 1918. Results of experiments with miscellaneous substances against bedbugs, cockroaches, clothes moths, and carpet beetles. U. S. Dept. Agr. Bul. 707.

Sweetman, H. L., D. A. Benson, and R. W. Kelly, Jr., 1953. Efficacy of aroma of cedar in control of fabric pests. JOUR. ECON. ENT. 46(1): 29–33.

Effect of Systemic Insecticides upon Certain Peanut Insects and upon Peanuts

B. WAYNE ARTHUR and F. S. ARANT, *A.P.I. Agricultural Experiment Station, Auburn, Alabama*

The introduction of systemic insecticides offered the possibility of improved control of thrips and other insect pests attacking peanuts in southeastern Alabama. Little or no information is available on the use of systemics on peanuts, but their use on cotton and other plants has resulted in the control of spider mites and aphids.

Smith & Fulton (1950) found that potato plants absorbed enough schradan to give effective control of the cotton aphid, *Aphis gossypii* Glov. Davich & Apple (1951) reported similar results in the control of the pea aphid, *Macrosiphum pisi* (Harr.), on peas. Davis & Sessions (1953), in reporting on the systemic action of demeton on cotton, found that demeton was highly effective against two species of spider mites, *Tetranychus bimaculatus* Harvey, and *T. pacificus* McG. Sherrer & Arant (1953) determined the LD-50 concentrations of *compound 21/116* (dimethyl analog of demeton) and demeton as 0.6 and 2.2 pounds per acre, respectively, on the control of the southern red mite, *Paratetranychus ilicis* McG., on camellias.

The tobacco thrips, *Frankliniella fusca* (Hinds), is the principal species involved in causing widespread stunting of seedling peanuts over most of the peanut-producing areas in Alabama. Wilson & Arant (1949) and Arant (1954) showed that thrips can be controlled on runner and Spanish peanuts with DDT or toxaphene dust, but yield increases from the use of either material varied from none to 92 pounds per acre. The practicability of thrips control is in doubt.

In order to study further the relationship of thrips damage and yield of peanuts, experiments were conducted in 1952 and 1953 to determine the effect of certain systemic insecticides on the control of thrips and to determine the effect of the chemicals on plant growth and yield of peanuts. The effectiveness of the systemic insecticides was compared with the effectiveness of DDT and toxaphene in the control of thrips and upon yield of peanuts. The systemic insecticides used were demeton, schradan, *Chlorthion*,[1] and *compound 21/116*.[2]

PROCEDURE.—Treatments were arranged in randomized complete blocks and were replicated four times. Each plot consisted of 4 rows, 3 feet apart, 33.3 feet long. Three-foot alleys were left between blocks of plots, and one buffer row was left between treatments in a block.

Demeton was the only systemic insecticide applied to the soil. The 50 per cent demeton emulsion was diluted with No. 2 fuel oil and applied to the seedbed with a soil fumigant injector 10 days before planting. As soon as the peanuts were up to a uniform stand, emergence sprays of demeton, schradan, *Chlorthion*, *21/116*, DDT, and toxaphene were applied to the foliage of the plants on certain plots. The sprays were applied with a carbon dioxide

[1] 0-0-dimethyl, 0,3,chloro-4 nitrophenyl thiophosphate.
[2] (Dimethyl analog of demeton) 0-[2-(ethylmercapto) ethyl] 0,0-dimethyl thiophosphate.

Table 1.—Average number of thrips per 20 bud tips of peanuts following systemic and standard insecticidal treatments.[1] Headland, 1952.

Treatment and Dates Applied	Pounds per Acre	Number of Thrips on 20 Vine Tips on Dates Indicated		
		5/17	5/24	5/31
Untreated check	—	24.0	22.7	29.7
Schradan, foliage, 5/7	1	8.7	5.7	37.5
Demeton, soil, 4/9	1	1.7	0.2	3.0
Demeton, foliage, 5/7	0.5	1.5	1.7	6.2
Demeton, soil, 4/9; foliage, 5/7	1 & 0.5	2.0	0.7	1.2
DDT, foliage, 5/7–19	1	13.5	1.0	1.0
Toxaphene, foliage, 5/7–19	2	6.5	0.2	0.7
L.S.D. at 5% level		4.89	5.18	4.10
1% level		6.61	6.99	11.37

[1] Based on four replications.

pressure sprayer. Later applications were made on certain plots at various intervals throughout the season.

Thrips population counts were made from the two outside rows of each plot. Twenty vine tips, consisting of 3 or 4 leaflets on seedling plants or 20 bud tips approximately 2 inches in length on larger plants, were taken from each plot for each infestation count.

During the summer of 1952 and again in 1953, heavy infestations of lepidopterous larvae, mainly corn earworm, *Heliothis armigera* (Hbn.), and fall armyworm, *Laphygma frugiperda* (A. & S.), were found on the foliage of the plants. Larval infestations were determined by counting the number of larvae found on 2 feet of row on one of the outside rows of each treatment. To prevent the larvae from affecting the yield of peanuts in the experiment, all plots including the untreated checks were dusted with cryolite at the rate of 20 to 25 pounds per acre for larval control.

Throughout the growing season, records were kept on the size of the plants and amount and nature of foliage injury to plants on each plot.

The center rows of each plot were harvested for yield records. Yields were based on sound, mature kernels per acre at 7 per cent moisture. In computing the sound, mature kernels per acre, a 100-gram sample of peanuts was shelled, and the peanuts were divided into sound, mature kernels and shrivels. The weight of mature kernels was used to calculate yield of sound, mature kernels per acre.

RESULTS.—Severe infestations of thrips occurred on the foliage of seedling peanuts on all plots except those receiving demeton as a soil treatment prior to planting. Summarized results from all treatments in terms of thrips populations for 1952 are presented in table 1.

Demeton applied to the soil, and schradan, demeton, DDT, and toxaphene applied to the foliage were effective in reducing thrips populations. Demeton, when applied to the soil, foliage, or soil and foliage, was significantly better for thrips control than schradan 24 days after application. Counts made after the first application of DDT, toxaphene, and demeton to the foliage showed that demeton gave slightly better control of thrips, but after the second application little difference was noted. DDT and toxaphene gave no control 21 days after the last application of spray was made.

Results of thrips population counts for 1953 are presented in table 2. Significant reductions of thrips were obtained on all treated plots for a period of 20 days as indicated by the first and second population counts. Thirty days after application of emergence sprays, the systemics were no longer effective and the applications were repeated. Significant control resulted from all treatments as indicated by the fourth and fifth infestation counts. Demeton applied to the soil was significantly better than any other treatment for thrips control at the time of the first population count and continued to give significant control for 67 days after date of application. Demeton was more effective than schradan, *Chlorthion*, or *21/116* in controlling thrips.

DDT and toxaphene were as effective in thrips control as foliage applications of the systemic insecticides where counts were made within 4 days after date of application. Demeton applied to the foliage or as a soil treatment resulted in better control of thrips and for a longer period of time than foliage applications of DDT and toxaphene.

Corn earworm and fall armyworm infestations became heavy during midsummer of 1952 and 1953. Population counts made 36 hours or 72 hours after spraying showed that demeton, schradan, *Chlorthion*, or *21/116* did not give significant control of corn earworm or fall armyworm.

Differences in rate of growth and amount of injury to plant foliage from the various spray applications were evident

Table 2.—Average number of thrips per 20 tips of peanuts following systemic and standard insecticidal treatments.[1] Headland, 1953.

Treatment and Dates Applied	Pounds per Acre	Number of Thrips on 20 Bud Tips on Dates Indicated				
		5/25	5/28	6/8	6/12	6/19
Untreated check	—	62.6	52.5	66.0	27.5	34.7
Schradan, foliage, 5/9	1	33.0	29.2	48.5	5.7	14.5
Demeton, soil, 4/11	1	4.5	0.2	26.0	5.0	15.2
Demeton, foliage, 5/9	0.5	22.5	23.5	44.4	15.5	25.5
Demeton, soil, 4/11; foliage, 5/9	1 0.5	3.5	4.5	23.5	0.5	4.0
Chlorthion, foliage, 5/9	0.5	28.2	22.2	41.5	0.0	18.2
21/116, foliage, 5/9	0.5	25.7	24.0	60.0	1.5	18.2
DDT, foliage, 5/9–25	1	25.0	0.7	23.7	8.5	19.7
Toxaphene, foliage, 5/9–25	2	19.5	1.5	26.2	13.2	21.0
L.S.D. at 5% level		12.93	8.34	12.70	5.82	7.57
1% level		17.37	11.21	17.07	7.82	10.17

[1] Based on four replications.

during the early part of the growing season. Plants receiving toxaphene, DDT, and schradan appeared greener in color and larger in size than did demeton-treated plants or plants receiving no treatment. Plants treated with *21/116* or *Chlorthion* were equal in size to the untreated plants. As the growing season progressed, the differences in size of plants became less apparent, and by harvest time no differences were noted.

Spray applications of demeton and schradan to the foliage at emergence apparently burned the margin of the leaves. As the plants became older, burning of the foliage by demeton was less evident, but schradan continued to produce noticeable burning throughout the season. *Chlorthion* caused light foliage injury to the outer margin of the leaves. DDT, toxaphene, and *21/116* caused no noticeable burning at any time during the season.

Average yields based on sound, mature kernels at 7 per cent moisture are presented in table 3. No significant differences existed between yields on plots treated with systemic insecticides and those receiving no insecticidal treatment. However, the trend was toward reduced yields on plots which received foliage applications of schradan at 30-day intervals throughout the season. Greater yield increases were obtained from plots where demeton was applied to the soil than from plots receiving foliage applications. Demeton applied to the soil prior to planting

Table 3.—Yield of peanuts from plots receiving systemic and standard insecticidal treatments,[1] Headland.

Treatment	Pounds per Acre	Number of Applications 1952	Yield/Acre 1952	Number of Applications 1953	Yield/Acre 1953
Untreated check	—	—	1,158	—	800
Schradan, foliage	1	5	996	4	723
Demeton, soil	1	1	1,213	1	901
Demeton, foliage	0.5	1	1,243	1	788
Demeton, soil & foliage	1 & 0.5	1 & 5	845	1 & 4	855
Demeton, foliage	0.5	5	1,134	4	909
Chlorthion, foliage	0.5	—	—	4	860
21/116, foliage	0.5	—	—	4	868
DDT, foliage	1	2	1,083	2	903
DDT, foliage	1	6	1,237	6	1,031
Toxaphene, foliage	2	2	1,023	2	925
Toxaphene, foliage	2	6	1,042	6	1,067
L.S.D. at 5% level					147
1% level					198

[1] Based on four replications.

and to the foliage throughout the growing season reduced the yield of peanuts 313 pounds in 1952 when compared with the yield of the untreated checks; however, the yield from the same treatment was slightly higher than the yield of the untreated check in 1953. Peanuts sprayed with *Chlorthion* or *21/116* produced higher yields than the checks, but the differences did not approach significance.

Plots receiving six applications of DDT or toxaphene produced significantly higher yields in 1953 than the untreated checks. Although two applications of DDT or toxaphene early in the growing season reduced significantly the population of thrips, plots receiving these treatments did not produce significantly more peanuts than the untreated checks. There was a trend toward increased yields resulting from thrips control in 1953.

Yields from peanut plots treated with systemic insecticides were lower than those treated with DDT or toxaphene. With few exceptions, plots receiving demeton, schradan, *Chlorthion*, or *21/116* produced significantly fewer peanuts than those receiving corresponding treatments with DDT or toxaphene. These differences were more pronounced in 1953 than in 1952.

SUMMARY.—Replicated field experiments were conducted during 1952 and 1953 on control of thrips, *Frankliniella fusca* (Hinds), attacking peanuts. Several systemic insecticides as well as DDT and toxaphene reduced significantly the population of thrips, but increases in yield of peanuts were not significant. Demeton applied to the soil or applied to the foliage gave better control of thrips than did schradan, *Chlorthion*, or *compound 21/116*. Demeton was as effective in thrips control as DDT or toxaphene and controlled them for longer periods of time, giving some control for 2 months after application to the soil.

Infestation counts made before and after spray application revealed that none of the systemic insecticides controlled corn earworm, *Heliothis armigera* (Hbn.), or fall armyworm, *Laphygma frugiperda* (A. & S.).

Demeton, applied at 30-day intervals throughout the growing season, apparently retarded the growth of the peanut plants. Demeton, schradan, and *Chlorthion* caused some burning of the foliage when the plants were young.

There was no significant increase in yield of peanuts when the systemic insecticides were applied to the soil before planting or to the foliage of the plants. Although the insecticidal treatments applied early in the growing season resulted in significant reductions in thrips populations, no significant increase in yield of peanuts was obtained. In 1953, yield increases were obtained which approached significance on plots receiving two early applications of DDT or toxaphene for thrips control.

LITERATURE CITED

Arant, F. S. 1954. Control of thrips and leafhopper on peanuts. JOUR. ECON. ENT. **47**(2): 257–63.

Davich, T. B., and J. W. Apple. 1951. Pea aphid control with contact and systemic insecticidal sprays. JOUR. ECON. ENT. **44**(4): 528–33.

Davis, Donald W., and A. C. Sessions. 1953. On the systemic action of systox on cotton. JOUR. ECON. ENT. **46**(3): 526–7.

Sherrer, Jack D., and F. S. Arant. 1953. Effect of certain systemic compounds on southern red mite infesting camellias. JOUR. ECON. ENT. **46**(6): 1116–7.

Smith, F. F., and R. A. Fulton. 1950. Toxicity of organic phosphates to the two-spotted spider mite and the foxglove aphid. JOUR. ECON. ENT. **43**(5): 627–32.

Wilson, Coyt, and F. S. Arant. 1949. Control of insects and diseases of peanuts. Ala. Agr. Expt. Sta. Leaf. 27.

Soil Application of Insecticides to Control Plum Curculio

C. L. Fluke and D. A. Dever,[1,2] *University of Wisconsin, Madison*

Many of the newer insecticides are effective against the plum curculio when applied as tree sprays (Bobb 1950, Chandler 1950, Snapp 1949). Tree applications are directed against the adults. However, some of the insecticides used are slow acting and thus give the adults a chance to oviposit before they are killed. It would appear more desirable to attack the curculio before it has had a chance to attack the fruit.

Snapp (1940) attempted to control the plum curculio by soil applications of dichloroethyl ether. He obtained excellent results with 1 fluid ounce per gallon of water on 1 square yard of soil. In 1942 Snapp indicated that 12 jarring operations per season must be used to supplement the soil application of dichloroethyl ether. In a later paper, Snapp (1945) concluded that the use of dichloroethyl ether, without jarring, was only slightly better than three applications of lead arsenate. Chandler (1946) failed to substantiate these results using the same materials and techniques.

Bobb (1946) found that DDT was ineffective when applied to the soil at the rate of 12 to 25 pounds per acre. However, using 0.5 and 1.0 pound of the gamma isomer of BHC he obtained 28.1 and 60.9 per cent control, respectively. Snapp (1947) found that the effectiveness of BHC as a soil application was of no practical value. In a later paper (Snapp 1949) found that parathion (at the rate of 6 lbs. of the 25% wettable powder to the acre and used at the rate of 1 gallon of liquid mixture per 6 square yards of soil) was effective. In preliminary experiments, Fluke & McIntyre (1952) found that soil applications of aldrin and dieldrin were effective. In 1953, Snapp (1953) substantiated these results when he reported satisfactory control using aldrin and dieldrin at the rate of 2 or 4 pounds per acre.

The Experiments in Wisconsin were begun at Gays Mills in the spring of 1951. The insecticides were added to orchard soils to test their effectiveness against both plum curculio and apple maggot. After 3 years, two of the insecticides, aldrin and dieldrin, were still toxic to plum curculio but none of the insecticides were satisfactorily toxic to the apple maggot.

Table 1.—Emergence of adults of plum curculio and apple maggot from treated soils, Gays Mills, Wisconsin.

Material Used[1]	Plum Curculios Emerged in Spring				Apple Maggots Emerged in Summer		
	1952	1953	1954[2]	Totals	1952	1953	Totals
Aldrin	0	1	0	1	24	82	106
Dieldrin	4	0	0	4	16	30	46
Chlordane	285	88	4	377	42	71	113
Lindane	67	71	16	154	56	54	110
EPN-300	488	139	18	645	40	33	73
Untreated	855	63	12	930	50	51	101

[1] Applied at the rate of 6 pounds per acre.
[2] Exceedingly wet spring following a below normal snow coverage may have influenced the small number of curculios found. Low counts also occurred in Door County.

Methods and Materials.—In early June 1951, 24 cages 2 feet by 2 feet by 14 inches high were placed over soil plots 3 feet by 3 feet in an old unsprayed orchard. The plots were treated with 6 pounds of actual insecticide to the acre, using aldrin, dieldrin, lindane, chlordane, and EPN-300.[3] Each treatment, including a check was replicated four times. Two gallons of water with the proper amount of insecticide was applied to each block.

During the spring and early summer, apples infested with plum curculio eggs and larvae were placed in the cages. In the fall, apples infested with apple maggots were added to these same cages. This procedure has been followed each year since the tests started with the exception of leaving out the maggoty apples after the second year.

Counts of the live adult curculios were made in May and June of each year, and of the apple maggot adults in July and August. These counts are given in table 1.

In June 1952, a new series of similar cages were constructed over sod treated areas in an open field in Door County. Aldrin, dieldrin, lindane, and chlordane were again used but at two strengths, repeating the 6-pound application and adding a series at 3 pounds to the acre. The

[1] Graduate Assistants, C. B. McIntyre, Frank Strong and Lorin Stelzer were associated with the project in 1951, 1952, nad 1953–4 respectively.

[2] Project supported by Wisconsin Alumni Research Foundation; additional financial help was given by Shell Chemical Corporation.

[3] A phosphate product made by E. I. du Pont de Nemours & Company, Inc.

Table 2.—Emergence of plum curculio adults from treated soils, Door County, Wisconsin.

Materials Used	Pounds per Acre	Plum Curculios Emerged in Spring		
		1953	1954	Totals
Aldrin	6	0	0	0
Aldrin	3	0	0	0
Dieldrin	6	0	0	0
Dieldrin	3	0	0	0
Chlordane	6	0	0	0
Chlordane	3	6	0	6
Lindane	6	1	1	2
Lindane	3	9	0	9
Untreated		147	62	209

design was the same as at Gays Mills, namely a randomized complete block. Each treatment was replicated four times. Plum curculio infested apples were added to these cages in July 1952 and 1953. The counts were made in the spring of 1953 and 1954. EPN-300 was omitted since the preliminary work at Gays Mills indicated its nonresidual toxicity to curculios in the soil. These results are given in table 2.

The results of the cage tests prompted tests on soil application of insecticides under orchard conditions. A heavily sodded orchard with a previous history of high curculio infestations (50 to 90 per cent by actual count on the fruit) was selected for the test. An area of 6 acres was divided into 18 plots of approximately $\frac{1}{3}$ acre per plot. This provided plots of 40 mature sour cherry trees (Montmorency), five rows wide and eight rows long. Six treatments (aldrin, dieldrin and heptachlor at 3 and at 6 pounds to the acre) were arranged in a randomized complete block design. Four of the plots were left untreated to serve as checks. The insecticides were applied to the soil in 900 gallons of water per acre using the ground boom developed by Keitt & Moore (1945) for ground treatment directed against apple scab.

Evaluations of these applications were made by two methods. First, 100 fruits on each of four trees in each plot (average 32 spurs per tree) were examined and the infestation recorded. Second, cages 2 feet by 2 feet covered with wire screen were placed in the orchard. Four of these cages were placed in each of the plots. Records were then taken on the curculios found in the cages. Although four cages were placed in each plot, the area of ground covered in comparison to the total area was exceedingly small. This method would be effective if curculio infested fruits were added to the cages as reported for the controlled cage tests. Only one curculio was found in all 64 cages. However, the spur records reported in table 3 were indicative of the effectiveness of the soil applications.

Discussion.—In the cage tests, all of the materials showed some toxicity to the plum curculio when applied to the soil at 3 or 6 pounds to the acre. Aldrin and dieldrin were superior to the chlordane, lindane, and EPN-300 test at Gays Mills (Table 1). In Door County, however, chlordane and lindane also appeared effective (Table 2). The soil in Gays Mills (Fayette-Dubuque loam is slightly acid) and that in Door County (Superior loam-alkaline) is different. It has already been postulated (Chandler 1946) that the soil type may alter the effectiveness of soil applications. This may account for the differences noted in the toxicity of chlordane and lindane.

The application of these materials under practical orchard conditions appears promising (Table 3). The evaluation of these insecticides based on tree infestation is questionable. Many curculios could live over in the soil of the untreated plots and spring migration might tend to nullify the effect of the insecticidal treatment in the treated areas. However, the reduction in infestation in the treated area (90 per cent in 1952) to an average of 4.9 per cent in 1954 is considered significant since neighboring orchards had as high as 50 per cent infestation of plum curculio in 1954. However,

Table 3.—Plum curculio incidence on tree fruit. Montmorency cherry. Door County, Wisconsin, 1954.

Material Used	Pounds Actual per Acre	Average Number Infested Cherries per 100
Aldrin	3	4.5
	6	4.0
Dieldrin	3	7.5
	6	5.5
Heptachlor	3	3.5
	6	2.7
Check	0	6.8
Overall Average		4.9

to obtain exact data on the relative toxicity of each insecticide to the plum curculio it would be desirable to cage curculio infested fruits and record the per cent emergence of adult beetles.

CONCLUSIONS.—In controlled cage tests aldrin and dieldrin were toxic to plum curculio adults when applied to the soil at 3 or 6 pounds to the acre. Both of these insecticides show a residual toxicity at 6 pounds to the acre after 3 years in the soil. Chlordane and lindane produced variable results which may be due to differences in soil type.

In field experiments, aldrin, dieldrin and heptachlor appeared to be effective in lowering the percentage of infestation in a heavily sodded orchard with a previous record of high infestations. The relative toxicity of each and exact rate of application (whether 3 or 6 pounds to the acre) were not established.

None of the insecticides used with the possible exception of dieldrin showed any toxicity to the apple maggot when applied as soil treatments. However, even the apparent mortality obtained with dieldrin was not high enough to warrant soil application of dieldrin for apple maggot control.

LITERATURE CITED

Bobb, M. L. 1946. Benzene hexachloride in plum curculio control. Virginia Fruit **35**: 47–53.
Bobb, M. L. 1950. Insecticides for the control of plum curculio. JOUR. ECON. ENT. **43**(2): 157–60.
Chandler, S. C. 1946. Unsatisfactory control of the plum curculio in Illinois with dichloroethyl ether. JOUR. ECON. ENT. **39**(5): 666–7.
Chandler, S. C. 1950. Comparative studies of insecticides for control of the plum curculio. JOUR. ECON. ENT. **43**(1): 73–5.
Fluke, C. L., and C. B. McIntyre. 1952. Plum curculio control through soil appliction of insecticides. Proc. Ann. Meet. North Cent. Branch Amer. Assoc. Econ. Ents. **7**: 24.
Keitt, G. W., and J. Duain Moore. 1945. Apple scab control experiments with ground and tree spraying for 1945. Wis. Hort. **36**(7): 166–7.
Snapp, O. I. 1940. Dichloroethyl ether for the control of the plum curculio attacking peaches. JOUR. ECON. ENT. **32**(4): 486–90.
Snapp, O. I. 1945. Further experiments with dichloroethyl ether for plum curculio control. JOUR. ECON. ENT. **38**(4): 417–22.
Snapp, O. I. 1947. Benzene hexachloride for control of plum curculio on peaches. JOUR. ECON. ENT. **49**(3): 382–5.
Snapp, O. I. 1949. New insecticides for plum curculio control—Second Report. JOUR. ECON. ENT. **42**(1): 7–11.
Snapp, O. I. 1953. Aldrin and dieldrin as soil insecticides to control plum curculio. JOUR. ECON. ENT. **46**(1): 180.

Aphid Collections in the Yakima Valley of Washington, 1947–53

E. W. DAVIS,[1] B. J. LANDIS, and K. E. GIBSON, *Entomology Research Branch, Agr. Res. Service, U.S.D.A.*[2]

Incidental to studies on the biology and control of aphids affecting potatoes in the Yakima Valley of Washington from 1947 to 1953, 139 species of aphids were collected in that area. We present below a list of these species with information on host plants and collection data. The aphids were identified by L. M. Russell, then of the U. S. Bureau of Entomology and Plant Quarantine, E. O. Essig, of the University of California, and G. F. Knowlton, of the Utah State Agricultural College. The plants were identified by X. M. Gaines, Department of Botany, Washington State College.

Palmer (1952) listed all aphid records in Colorado and adjacent territory up to 1950. Newton *et al.* (1953) published a list of 44 species, showing local distribution of aphids collected on sticky boards hung in peach trees at Palisade, Colorado.

The various plant species examined to determine their importance as hosts of the green peach aphid, *Myzus persicae* (Sulz.), and the potato aphid, *Macrosiphum solanifolii* (Ashm.), provide the host-plant records. Under some condi-

[1] Deceased October 24, 1954.
[2] In cooperation with the Washington State Department of Agriculture and the Washington Agricultural Experiment Stations.

Species of aphids collected in the Yakima Valley of Washington, 1947–53

Species	Collection Dates		Hosts
	Earliest	Latest	
Amphorophora arbuti Dvds.	6-2	7-28	In flight
nervata (Gill)	4-16	11-13	*Solanum tuberosum; Rosa* sp. (wild and cultivated); in flight
sonchi (Oestl.)	5-14	11-3	*Solanum tuberosum; Lactuca* sp.; *Ribes* sp. (M, F); in flight
urtica Essig	6-19	6-19	*Urtica* sp.
Anoecia corni (Fabr.)	7-10	10-16	In flight
querci Fitch	10-6	10-30	In flight
Aphis armoraciae (Cowen)	4-30	10-21	*Helianthus* sp.; *Mentha piperita;* in flight
bakeri Cowen	8-14	11-8	*Solanum tuberosum;* in flight
cardui (L.)	5-8	11-7	In flight
coweni Palmer	10-2	10-2	In flight
eriophori Walker	10-2	11-6	In flight
fabae Scop.	6-16	11-7	*Solanum tuberosum; Sonchus oleraceus; Spinacia oleracea; Cucurbita maxima; Eschscholtzia californica; Chenopodium album; Lactuca* sp.; *Salix* sp. (M, F); in flight
gossypii Glover	6-24	10-24	*Cucurbita maxima; Chenopodium album; Asclepias speciosa; Typha latifolia; Solanum tuberosum;* in flight
helianthi Monell	5-6	9-19	*Helianthus annuus; Sonchus oleraceus; Asclepias speciosa;* in flight
helichrysi (Kalt.)	4-13	11-3	*Prunus* sp.; *Amsinckia intermedia; Solanum tuberosum;* in flight
heraclella Davis	5-17	7-28	*Pastinaca sativa; Petroselinum crispum;* in flight
incognita (H. & F.)	8-12	8-12	In flight
kachena Hottes	9-22	9-22	In flight
maidi-radicis Forbes	4-30	10-28	*Solanum nigrum* roots; in flight
medicaginis Koch	4-12	9-11	*Robinia* sp.; *Chenopodium album; Descurainia sophia;* in flight
nasturtii Kalt.	7-10	7-10	In flight
persicae-niger Smith	5-5	10-27	*Prunus persica; Salix* sp. (M, F); in flight
pomi DeG.	5-24	9-4	*Malus sylvestris;* in flight
rosea (Baker)	9-25	11-6	In flight
rubicola Oestl.	6-2	6-2	In flight
rumicis L.	5-8	10-24	*Brassica oleracea; Spinacia oleracea; Eschscholtzia californica; Rumex* sp.; *Cucurbita maxima; Cucurbita pepo; Viburnum* sp.; *Chenopodium album; Arctium lappa; Brassica rapa; Rheum rhaponticum;* in flight
Sambucifoliae Fitch	7-31	7-31	In flight
sensoriata G. and B.	8-7	11-20	In flight
setariae (Thomas)	9-19	9-19	In flight
spiraecola Patch	5-1	10-27	*Spiraea* sp. (M, F, O); *Celastrus* sp. (M, F, O); in flight
viburnicola Gill	4-14	11-13	*Viburnum* sp. (M, F); in flight
viburniphila Patch	7-31	7-31	In flight
pruni W, and D.	7-10	7-10	*Ribes* sp.
Brevicoryne brassicae (L.)	4-15	10-24	*Solanum tuberosum; Brassica oleracea; Brassica campestris;* in flight
symphoricarpi (Thomas)	6-27	7-3	*Symphoricarpos albus*
Calaphis coloradensis Gran.	6-5	9-11	In flight
Capitophorus bragii (Gill)	5-25	11-8	*Salix* sp. (M, F); *Solanum tuberosum;* in flight
fragaefolii (Cock.)	4-7	7-21	*Malva neglecta; Fragaria chiloensis; Rosa* sp.
hippophaes (Walker)	6-9	11-8	*Polygonum* sp.
oestlundi Knowlton	4-17	4-17	*Chrysothamnus* sp.
pseudoglandulosus Pal.	7-7	7-7	In flight
ribis (L.)	6-12	9-15	In flight
wasatchii Knowlton	4-17	4-17	*Chrysothamnus* sp.
xanthii (Oestl.)	5-29	5-29	*Solanum tuberosum; Lepidium perfoliatum* (A)
Cavariella aegopodii (Scopoli)	5-2	10-9	*Anethum graveolens; Fragaria chiloensis; Solanum tuberosum; Aquilegia vulgaris*
pustula Essig	10-20	10-20	In flight
Chaitophorus populellus G. and P.	6-29	6-29	*Populus* sp.
viminalis Monell	7-10	10-27	*Salix* sp. (M, F, O)

(*continued*)

SPECIES	COLLECTION DATES		HOSTS
	Earliest	Latest	
Cinaria curvipes (Patch)	8-28	8-28	In flight
sabinae (G. and B.)	6-19	6-19	In flight
Drepanaphis acerifolii (Thomas)	5-8	10-24	*Prunus* sp. (M); in flight
Drepanosiphum bragii Gill	10-24	10-24	*Brassica campestris* (A)
platanoides (Schnk.)	5-22	11-13	In flight
Eichochaitophorus populifolii Essig	6-16	8-4	In flight
Epaneibaphis frigida (Oestl.)	10-28	10-28	In flight
Eriosoma americanum (Riley)	5-29	5-29	In flight
lanigerum (Hausm.)	6-26	11-3	*Malus sylvestris;* in flight
Essigella californica (Essig)	9-22	9-22	In flight
Euceraphis betulae (Koch)	9-8	9-8	In flight
Forda formicaria Heyden	5-8	6-12	*Phaseolus vulgaris* (A); in flight
olivaceae Rohwer	6-23	6-23	In flight
Hyalopterus arundinis (Fabr.)	4-13	11-7	*Solanum tuberosum; Prunus* sp.; *Typha latifolia; Prunus armeniaca; Lactuca* sp.; *Celastrus* sp. (M, F)
atriplicis (L.)	5-27	9-10	*Chenopodium album; Solanum tuberosum;* in flight
Kakimia cerei G. and P.	6-7	6-7	In flight
essegi (G. and P.)	5-20	10-28	*Aquilegia vulgaris* (M, F, O)
Lachnus salignus (Gmelin)	11-7	11-7	*Salix* sp.
Macrosiphum ambrosiae (Thomas)	7-3	9-21	*Helianthus annuus, Amaranthus* sp.; *Aster* sp.
atripes G. and P.	7-10	7-10	*Solidago* sp.
audeni MacD.	7-28	7-28	In flight
barri Essig	7-7	10-6	*Lactuca* sp.; in flight
dirhodum (Walk.)	4-18	10-24	*Solanum tuberosum; Rosa* sp. (wild and cultivated); in flight
Macrosiphum coessigi Knowlton	6-6	6-6	*Althaea rosea*
erigeronensis (Thomas)	7-10	7-10	*Lactuca* sp.
granarium (Kirby)	4-13	10-24	*Triticum aestivum; Solanum tuberosum;* in flight
katonkae (Hottes)	6-26	6-26	In flight
ludovicianae (Oestl.)	7-31	8-7	In flight
pelargonii (Kalt.)	4-7	11-8	*Erodium cicutarium; Amsinckia intermedia; Vicia villosa; Lupinus* sp.
pisi (Kalt.)	3-23	10-24	*Solanum tuberosum; Vicia villosa; Erodium cicutarium; Medicago sativa; Pisum sativum*
rosae (L.)	5-20	10-23	*Rosa* sp.
rudbeckiae (Fitch)	6-9	7-21	Aster sp.; in flight
sanborni Gill	9-18	10-24	*Chrysanthemum* sp.
solanifolii (Ashm.)	2-11	11-3	*Solanum tuberosum; Asclepias speciosa; Cucurbita maxima; Solanum villosum; Sisymbrium altissimum; Cardaria pubescens; Lactuca* sp.; *Eschscholtzia californica; Arctium lappa; Brassica rapa; Physalis* sp.; *Chenopodium album; Spinacia oleracea; Amsinckia intermedia; Descurainia sophia; Lepidium perfoliatum; Vicia villosa; Symphoricarpos albus; Solanum nigrum; Malva neglecta; Rosa* sp.; *Catalpa* sp.; *Amaranthus* sp.
subviride MacD.	7-7	7-7	In flight
taraxaci (Kalt.)	5-17	7-3	In flight
zerozalphum Knowlton	2-20	4-24	*Erodium cicutarium; Malva neglecta*
Mycromyzus oliveri Essig	3-27	3-27	*Viola* sp.
Mindarus abietinus Koch.	6-2	8-4	*Solanum tuberosum;* in flight
Monellia caryae (Monell)	6-6	10-6	In flight
Myzocallis coryli (Goetz)	10-27	10-27	In flight
ononidis (Kalt.)	7-14	7-14	In flight
robiniae (Gill.)	6-23	11-3	*Solanum tuberosum; Robinia* sp. (M, F); in flight
tiliae (L.)	7-31	7-31	In flight
trifolii (Monell)	8-4	8-4	In flight
ulmifolii (Monell)	6-30	7-14	In flight
Myzus cerasi (Fabr.)	6-11	11-6	*Prunus avium*

(*continued*)

Species	Collection Dates: Earliest	Collection Dates: Latest	Hosts
persicae (Sulz.)	2-15	11-7	[1]
porosus Sanderson	5-20	5-20	*Fragaria chileonsis*
solani (Kalt.)	2-19	11-8	*Solanum tuberosum; Solanum dulcamara; Malva neglecta; Lilium* sp.; *Iris* sp.
Neosymydobius annulatus (Koch)	5-25	9-22	*Betula alba;* in flight
Oestlundiella flava (Dvds.)	7-28	7-28	In flight
Pemphigus galsamiferae Williams	5-6	5-23	In flight
Pemphigus populi-ramulorum Riley	5-8	7-31	In flight
populi-transversus Riley	7-3	7-3	*Solanum tuberosum* (A)
populi-venae Fitch	7-28	7-28	In flight
Periphyllus caliorniensis Shinji	6-9	7-10	In flight
brevispinosus G. and P.	8-11	8-11	In flight
bruneri (Williams)	7-10	7-10	*Populus* sp.
lyropictus (Kessler)	5-8	10-23	*Acer* sp. (M, F); in flight
macrostachyae (Essig)	4-30	4-30	*Salix* sp.
negundinis (Thos.)	5-8	10-6	In flight
populicolus (Thomas)	5-24	8-11	*Populus* sp.; in flight
testudinacea (Fernie)	5-15	10-27	In flight
Phorodon humuli (Schrank)	4-14	11-7	*Prunus* sp.; *Humulus lupulus;* in flight
menthae (Buck.)	8-24	10-21	*Mentha piperita*
Prociphilus fraxinifolii (Riley)	7-10	7-10	*Solanum tuberosum*
venafuscus (Patch)	9-22	10-6	In flight
Pterocomma bicolor (Oestl.)	4-30	11-7	*Salix* sp.; in flight
populifoliae (Fitch)	9-25	9-25	In flight
pseudopopulea Palmer	5-28	5-28	*Solanum tuberosum* (A)
salicis (L.)	10-2	11-6	In flight
smithae (Monell)	10-6	11-13	*Populus* sp.; in flight
Rhopalosiphoninus latysiphon (Dvds.)	4-6	4-6	*Solanum tuberosum* tubers
Rhopalosiphum berberidis (Kalt.)	5-1	6-6	*Spiraea* sp.; *Berberis* sp.; in flight
conii (Davidson)	10-8	10-22	*Symphoricarpos albus* (M, F); in flight
fitchii (Sanderson)	4-13	11-3	*Sorbus sitchensis* (0); *Amsinckia intermedia; Malus floribunda; Prunus avium;* in flight
grabhami Cockerell	9-18	11-13	In flight
maidis (Fitch)	8-7	8-7	In flight
nymphaeae (L.)	7-17	8-12	In flight
pseudobrassicae (Davis)	4-7	10-24	*Brassica* sp.; *Sisymbrium altissimum; Descurainia sophia;* in flight
rufomaculata (Wilson)	6-5	7-7	In flight
scirpifolii G. and P.	6-23	6-23	In flight
serotinae Oestlund	6-23	7-10	*Solidago* sp.; in flight
splendens (Theobald)	10-23	10-23	In flight
Thecabius populi-monilis (Riley)	9-4	10-5	In flight
Thelaxes californica (Davidson)	6-2	6-2	In flight
Tinocallis platani (Kalt.)	5-22	10-27	In flight
Toxoptera graminum (Rondani)	5-14	5-14	*Solanum tuberosum;* in flight
Trama rara Mordvilko	6-9	6-12	In flight
Trifidaphis phaseoli (Passerini)	10-10	10-10	*Solanum tuberosum* roots

[1] According to Newton *et al* (1953), the host-plant list of this aphid includes 235 genera and 335 species. Since no new record can be added, it is needless to enumerate the many host plants found locally.

tions aphids produce winged forms, which migrate to various plants. Different types of traps were tested for collecting these migrating aphids. The tanglefoot screen described by Dudley *et al.* (1928) and the sticky trap board described by Kaloostian & Yeomans (1944) were tried and discarded because of the labor involved in removing the aphids. The wind trap described by Shands *et al.* (1942) and improved by Davis & Landis (1949) eliminated much of the labor but was less effective than the yellow trap pans of Moericke (1951). When tested side by side, the trap pans collected several times as many aphids as the wind traps.

To obtain information on heights at which the aphids were flying, trap pans were set on a tower constructed for the purpose, two each at ground level and at heights of 5, 10, 15, and 20 feet. The trap tower was operated during the seasons of aphid flight in 1952 and 1953. The pans were emptied each work day, and the

number of aphids caught in each pan was recorded.

The percentages of aphids trapped at different levels were similar for the 2 years. The average of the 2 years' collections showed that approximately 66 per cent were caught in the pans at the ground level, and 15, 9, 6, and 4 per cent at the 5, 10, 15, and 20-foot levels, respectively, on the trap tower. Species found in all types of traps are indicated in the host column as in flight.

Unless otherwise specified, wingless asexual forms were found on the indicated host. Where other forms were found, M (male), F (female), O (ovipara), and A (alate) are given in parenthesis.

The 139 species of aphids collected in the Yakima Valley include 12 species not previously recorded for the Rocky Mountain region and 12 reported by Palmer (1952) as being rare in that region.

LITERATURE CITED

Davis, E. W., and B. J. Landis, 1949. An improved trap for collecting aphids. U. S. Bur. Ent. and Plant Quar. **ET-278.**

Dudley, J. E., Jr., E. M. Searls and Alfred Weed. 1928. Pea aphid investigations. 4th Intern. Cong. Ent. Ithaca, N. Y., Trans. *2*: 608–21.

Kaloostian, G. H., and M. S. Yeomans. 1944. A sticky trap board used in scouting for pear psylla. U. S. Bur. Ent. and Plant Quar. **ET-220.**

Moericke, V. 1951. Eine Farbfalle zur Kontrolle des Fluges von Blattläusen insbesondere der Pfirsichblattlaus, *Myzodes persicae* (Sulz.). Nachrichtenbl. den Deuts. Pflanzenschutzdienst **3**(2): 23–4.

Newton, J. H., M. A. Palmer, and G. M. List. 1953. Fall migration of aphids with special reference to the green peach aphid. JOUR. ECON. ENT. **46**(4): 667–70.

Palmer, Miriam A. 1952. Aphids of the Rocky Mountain Region. 452 pp., 8 pl., Thomas Say Foundation, Vol. 5.

Shands, W. A., G. W. Simpson, and F. H. Lathrop. 1942. An aphid trap. U. S. Bur. Ent. and Plant Quar. **ET-196.**

Aphid Transmission of a Bean Yellow Mosaic Virus[1]

K. G. SWENSON, *New York State Agricultural Experiment Station, Geneva*

The bean yellow mosaic virus (bean virus 2, *Phaseolus virus* 2) not only causes an important disease of beans but also it is the cause of a virus disease of peas (Hagedorn & Walker 1950). This virus is commonly found in red clover (Hanson & Hagedorn 1952) and sweet clover (Pierce 1935). In addition, gladiolus may serve as a reservoir for bean yellow mosaic virus (McWhorter *et al.* 1947, Bridgmon & Walker 1952). Recently the writer isolated a virus of the bean yellow mosaic type from naturally-infected red clover near Geneva, N. Y. Studies of the host range and aphid transmission of this virus are reported herein.

METHODS.—In the host range studies, some plants were inoculated by aphids and others by rubbing with expressed sap (Rawlins & Tompkins 1936). The method of Rawlins & Tompkins is herein referred to as mechanical inoculation. The aphids were permitted to feed several hours on the virus source plant and then were transferred to the test plant where they were allowed to feed for 2 days. Ten aphids were placed on each test plant. In nearly all cases, whether inoculation was mechanical or by aphids, five Alaska pea plants were inoculated at the same time as each species or variety being tested for susceptibility. Usually four or five of the five Alaska pea plants inoculated were infected and, in no case, were less than two of the five infected. The symptoms on Alaska pea were constant and readily recognizable and appeared sooner than on other plants.

RESULTS.—The results of the host range studies are presented in table 1. Insofar as can be ascertained from the literature, the virus resembles more closely the bean yellow mosaic viruses (bean virus 2) of Pierce (1934, 1935) and of Hagedorn & Walker (1950) than any of the four viruses described by Zaumeyer (1940), although it differed somewhat

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal paper No. 966, June 4, 1954.

FIG. 1.—Symptoms produced on Stringless Green Refugee bean by a bean yellow mosaic virus. Center leaf from healthy plant. The three leaves were taken from the same position on three plants of the same age

from all these viruses. The symptoms on Stringless Green Refugee bean are shown in figure 1. No stunting or necrotic symptoms were produced on infected pea varieties. The virus was not latent in *Vicia sativa* as were the bean virus 2 isolates of Hagedorn & Walker (1950). Host range and symptomatology indicated that this virus is quite distinct from the pod-distorting strain of Grogan & Walker (1948). Necrotic symptoms in snap beans, such as described by McWhorter *et al.* (1947) were not produced.

In addition to the plants listed in table 1, two varieties of cucumber (National Pickling and Chicago Pickling) were inoculated mechanically with negative results.

Three groups of 10 alfalfa plants each were inoculated. No symptoms appeared on any of these plants. Sub-inoculations were made from the last group of 10 alfalfa plants to 30 Alaska pea plants in an effort to recover the virus from the alfalfa. These inoculations were made by means of the pea aphid, *Macrosiphum pisi* (Kltb.), using 10 aphids for each Alaska pea plant. No symptoms developed on any of the 30 Alaska pea plants. A larger number of alfalfa plants were inoculated and recovery attempts made because of the ecological importance of alfalfa in relation to pea virus diseases in western New York.

The bean yellow mosaic virus has been transmitted by *Macrosiphum pisi* (Kltb.) and *M. solanifolii* (Koch) (Pierce 1934, Hagedorn & Walker 1950). Several aphid species were tested for ability to transmit the New York virus. The aphids were fed on the virus source plant for several hours and then were transferred to healthy Alaska peas where they were left for 2 days. Ten Alaska peas were used for each aphid species, with 10 aphids per plant. The following results were obtained:

Aphic species	*Number plants infected*
Brevicoryne brassicae (L.)	0 of 10
Macrosiphum pisi (Kltb.)	8 of 10
M. solanifolii (Ash.)	6 of 10
Myzus persicae (Sulz.)	8 of 10

Experiments were conducted to determine how long non-feeding apterous pea aphids could retain the virus. The retention periods tested were $\frac{1}{4}$ hr., $\frac{1}{2}$ hr., 1 hr., 4 hrs. and 6 hrs. The aphids were placed on diseased clover plants (*Trifolium hybridum*) for a 3-minute acquisition feeding, after which they were placed in shell vials. At the end of each of the time intervals, aphids were removed from the shell vials

Table 1.—Reactions of legume species and varieties to inoculation with bean yellow mosaic virus isolated from red clover.

TEST PLANT	RE-ACTION[1]	METHOD OF INOCULATION
Medicago sativa L.		
Var. Kansas Common	0/20	*Macrosiphum pisi*
	0/10	*Myzus persicae*
Melilotus alba Desr.	4/10	*M. persicae*
Phaseolus vulgaris L.		
var. Idaho Refugee	8/17	Mechanical
var. Stringless Green Refugee	4/10	*M. pisi*
	10/10	*M. persicae*
var. U.S. No. 5 Refugee	2/14	Mechanical
Pisum sativum L.		
var. Alaska	8/10	*M. pisi*
Alderman	10/10	*M. persicae*
Perfected Wales	2/10	*M. pisi*
Perfection	0/10	*M. pisi*
	0/10	Mechanical
Soja max (L.) Piper		
var. Cayuga	0/10	*M. pisi*
Trifolium hybridum L.	10/10	*M. persicae*
T. incarnatum L.	2/10	*M. pisi*
T. pratense L.	4/10	*M. persicae*
T. repens L.		
var. Ladino	0/10	*M. pisi*
	0/10	*M. persicae*
Vicia faba L.		
var. major	2/10	Mechanical
Vicia sativa L.		
var. Willamette	10/10	*M. persicae*
Vigna sinensis Endl.		
var. California Blackeye	0/10	Mechanical

[1] Denominator = number of plants inoculated, numerator = number infected.

and placed, five aphids per plant, on healthy Alaska pea plants where they were left for 2 hours. The tests were conducted in replicates, each replicate including five Alaska pea plants for each period of time and five pea plants to which the aphids were transferred directly from the infected clover plant. The results are presented in table 2. The virus was retained from 4 to 6 hours, with no reduction in the rate of transmission occurring during the first $\frac{1}{2}$ hour.

Starving the pea aphid for $\frac{1}{2}$ hour before feeding on the virus source plant resulted in a rate of transmission approximately twice that of non-starved aphids. This effect of starvation and the relatively short period of retention indicate that transmission by aphids is of the nonpersistent type (Watson & Roberts 1939).

SUMMARY.—The work described herein was part of a proposed series of tests to identify the viruses affecting peas in western New York and to gain information concerning the factors affecting their relative prevalence in peas. In this respect, this study contributed two facts concerning the bean yellow mosaic virus. First, a virus retained by aphids for a period of 4 to 6 hours with greatly reduced rate of transmission after $\frac{1}{2}$ hour will, from this standpoint, not be as effectively spread as one which is retained for a much longer period, as is the pea enation mosaic virus. Secondly, in Western New York, a virus which does not infect alfalfa is likely to be of much less importance to peas than one which does infect alfalfa because alfalfa is the source of far more aphids migrating to pea than red clover in this area

Table 2.—Transmission of a bean yellow mosaic virus by pea aphids starved for various periods after acquisition feeding on the virus source.

POST-ACQUISITION FEEDING STARVATION PERIOD (IN HOURS)					
0[1,2]	1/4	1/2	1	4	6
14/30	17/30	13/30	9/30	2/30	0/25

[1] "0" starvation period indicates direct transfer from virus source plant to test plant.
[2] Denominator = number of plants inoculated; numerator = number of plants infected. Five aphids per plant.

LITERATURE CITED

Bridgmon, G. H., and J. C. Walker. 1952. Gladiolus as a virus reservoir. Phytopath. **42**: 65–70.

Grogan, R. G., and J. C. Walker. 1948. A pod-distorting strain of yellow mosaic virus of bean. Jour. Agr. Res. (U. S.) **77**: 301–14.

Hagedorn, D. J., and J. C. Walker. 1950. The relationship of bean virus 2 to pea mosaic in Wisconsin. Phytopath. **40**: 684–98.

Hanson, E. W., and D. J. Hagedorn. 1952. Red clover, a reservoir of legume viruses in Wisconsin. Phytopath. **42**: 467. (Abst.).

McWhorter, F. P., Lytton Boyle, and B. F. Dana. 1947. Production of yellow bean mosaic in beans by virus from mottled gladiolus. Science **105**: 177–8.

Pierce, W. H. 1934. Viroses of the bean. Phytopath. **24**: 87–115.

Pierce, W. H. 1935. The identification of certain viruses affecting leguminous plants. Jour. Agr. Res. (U. S.) **51**: 1017–39.

Rawlins, T. E., and C. M. Tompkins. 1936. Studies on the effect of carborundum as an abrasive in plant virus inoculations. Phytopath **26**: 578–87.

Watson, M. A., and F. M. Roberts. 1939. A comparative study of the transmission of *Hyoscyamus* virus 3, potato virus Y and cucumber virus 1 by the vectors *Myzus persicae* (Sulz.), *M. circumflexus* (Buckton) and *Macrosiphum gei* (Koch). Proc. Roy. Soc. Lond. B. **127**: 543–76.

Zaumeyer, W. J. 1940. Three previously undescribed mosaic disease of pea. Jour. Agr. Res. (U. S.) **60**: 433–52.

Control of Corn Earworm and Stored Grain Insects in Single-Cross Corn

W. G. EDEN,[1] *A.P.I. Agricultural Experiment Station, Auburn, Alabama*

Production of hybrid seed corn in the South is a rapidly expanding industry. The production of pure lines and single-crosses is an expensive operation, and yields are low in comparison with regular field corn. The corn earworm, *Heliothis armigera* (Hbn.), and stored grain pests, especially the rice weevil, *Sitophilus oryza* (L.), and the Angoumois grain moth, *Sitotroga cerealella* (Oliv.), do severe damage to the pure lines and single-crosses grown in Alabama. A control program is badly needed.

It has been shown within the past few years that the corn earworm can be controlled effectively in sweet corn (Anderson *et al.* 1952, Blanchard *et al.* 1951, Ditman, 1950, Eden 1952, 1953, Kulash 1950, Rutschky 1952, Wilson *et al.* 1952). Blanchard & Satterthwait (1945) reported promising results on control of the corn earworm with DDT in dent seed corn. Blanchard & Douglas (1953) recommended DDT-mineral oil sprays for the control of the corn earworm in seed-corn fields. Douglas & Smith (1953) reported that DDT-mineral oil sprays applied to corn for control of the corn earworm gave almost perfect control of the rice weevil.

An experiment on control of the corn earworm and stored grain insects in single-cross corn was conducted in 1953 at the Plant Breeding Unit of the A.P.I. Agricultural Experiment Station, near Tallassee, Alabama, and the results are presented in this paper.

PROCEDURE.—The experiment was conducted in a production field of F44 × F6 (Dixie 18 seed parent single-cross) corn. Plots consisted of four rows of the F44 inbred line across the entire field (40 acres). Treatments were replicated five times in randomized blocks. The treatments, which were all sprays, were applied with a high-clearance, self-propelled machine with an auxiliary motor-driven pump. The machine was equipped to spray four rows with two fan type (65067) nozzles on each side of each row. The nozzles were arranged to spray the ear region of the stalks. Sprays were applied at the rate of 30 gallons of spray per acre at 200-pound pressure.

Table 1.—Treatments, dates of application, and percentages of stalks in silk in corn earworm control experiment, Tallassee, Alabama, 1953.

TREATMENT[1] AND NO. OF APPLICATIONS	DATES OF APPLICATION AND PERCENTAGES OF STALKS IN SILK						
	7/10	7/13	7/16	7/18	7/21	7/24	7/27
	0	4	10	25	58	100	100
Untreated check							
DDT+oil, 4			X	X	X	X	
DDT+oil, 5			X	X	X	X	X
DDT+oil, 6		X	X	X	X	X	X
DDT+oil, 7	X	X	X	X	X	X	X
DDT, 4			X	X	X	X	
DDT, 5			X	X	X	X	X
DDT, 6		X	X	X	X	X	X
DDT, 7	X	X	X	X	X	X	X

[1] All sprays contained 2 pounds DDT per acre per application. Those containing mineral oil had 1.5 gallons per acre per application, which was formulated from Thompson-Hayward WE-5 Corn Earworm Spray.

Treatments were emulsion sprays containing 2 pounds of DDT per acre per application. Sprays were applied at 3-day intervals both with and without 1.5 gallons of mineral oil[2] per acre per application. The number of applications varied from four to seven. Treatments, dates of application, and percentages of stalks in silk on the spray dates are given in table 1.

The corn was harvested in early September. A 50-foot section of the 4-row plots was harvested from each replication of each treatment. The corn was husked, and the ears were rated for corn earworm damage. Four categories of injury were established as follows:

None; no visible worm damage
Light; damage not over ½ inch into the ear from the tip
Medium; damage not over 1½ inches
Heavy; damage over 1½ inches

The corn was dried, shelled, and weighed to determine yields. Yields were calculated on clean, marketable corn. Samples of approximately 500 kernels from each replication were examined for injury by stored grain pests. The acid-fuchsin stain method of Frankenfeld (1948) was employed.

RESULTS.—Results of the sprays on

[1] Acknowledgment is made to Dr. F. S. McCain, Corn Breeder, A.P.I. Agricultural Experiment Station, for his cooperation and assistance in conducting this experiment.

[2] Treatments receiving mineral oil were formulated from 2.5 gallons of Thompson-Hayward WE-5 Corn Earworm Spray.

Table 2.—Damage by the corn earworm and stored grain insects[1] and yields of single-cross corn following various spray treatments. Tallassee, Alabama, 1953.

Treatment and No. of Applications	Percentage of Earworm Damage by Categories				Percentage of Kernels Damaged by Stored Grain Insects	Yield in Bu. per Acre
	None	Light	Medium	Heavy		
Untreated check	0.3	1.0	44.7	54.0	12.5	12.3
DDT+oil, 4	8.7	4.3	60.8	26.3	4.7	14.1
DDT+oil, 5	22.0	8.7	52.8	16.5	4.2	12.7
DDT+oil, 6	26.5	10.6	43.2	19.7	4.2	11.9
DDT+oil, 7	25.5	10.1	46.7	17.7	4.5	12.6
DDT, 4	4.1	2.9	61.3	31.7	4.0	15.1
DDT, 5	5.9	3.2	66.2	24.6	3.4	13.6
DDT, 6	9.9	5.3	59.7	25.2	4.1	14.0
DDT, 7	7.0	7.8	56.5	28.7	4.8	14.6

[1] The rice weevil and the Angoumois grain moth were the principal species involved.

control of the corn earworm are presented in table 2. All treatments reduced the damage to the ears by the earworm. The DDT-mineral oil combination was more effective in controlling the earworm than DDT alone. Four applications of the DDT-oil resulted in more worm-free ears (no damage) than four, five, six, or seven applications of DDT alone. The same was true in the case of lightly damaged ears for four, five, or six applications of DDT alone; however, seven applications of DDT alone resulted in more lightly damaged ears than four applications of the DDT-oil spray. It is interesting to note that, with the exception of the untreated corn, the bulk of the ears in all treatments fell into the category of medium earworm damage. Six or seven applications were more effective in controlling the earworm than four or five. This was the case with either the DDT-oil combination or the DDT alone.

The results of the treatments on control of stored grain insects are also presented in table 2. Insects that were primarily responsible for the damage were the rice weevil, *Sitophilus oryza* (L.), and the Angoumois grain moth, *Sitotroga cerealella* (Oliv.). The untreated corn had an average of 12.5 per cent of the kernels damaged. The damage to the corn in the spray treatments was obviously less, falling between 3.4 and 4.8 per cent.

The average yields of clean, marketable seed corn for all treatments are presented in table 2. The highest yield of corn, 15.1 bushels per acre, was produced on the plots that received only four applications of DDT without oil. In all cases higher yields were obtained with DDT alone than with the DDT-oil combination. Although better earworm control was obtained with the DDT-oil combination than with DDT alone and the control of stored grain pests was the same in both cases, plots receiving DDT alone produced more seed corn per acre. Thus, it appears from these data that the oil had a detrimental effect on pollination or some other factor related to the yield potential of the plants.

The yields of corn in the experiment appear to be low and the differences between treatments small. Actually these yields are considered to be good for this particular single-cross corn, and the apparent small yield increases from spraying are economically feasible.

SUMMARY.—The production of hybrid seed corn is a rapidly expanding industry in the South. The corn earworm, *Heliothis armigera* (Hbn.), the rice weevil, *Sitophilus oryza* (L.), and the Angoumois grain moth, *Sitotroga cerealella* (Oliv.), do severe damage to the industry. An experiment was conducted in Alabama in 1953 on the control of these insects in single-cross corn. The best control of the earworm was obtained with six or seven applications of 2 pounds of DDT plus 1.4 gallons of mineral oil per acre per application. From four to seven applications of 2 pounds of DDT with or without mineral oil resulted in significant reductions in damage due to the rice weevil and the Angoumois grain moth, and there were no differences between the spray treatments. The highest yield of clean, marketable seed corn was produced on the plots that received four applications of DDT without mineral oil. The mineral oil appeared to have a detrimental effect on the yield of the corn.

LITERATURE CITED

Anderson, L. D., Bacon, O. G., Swift, J. E., and H. T. Reynolds. 1952. Corn earworm control on sweet corn. Calif. Agr. **6**(4): 8–9, 15.

Blanchard, R. A., and A. F. Satterthwait. 1945. Comparison of four insecticides, including DDT, in mineral oil for control of the corn earworm in dent seed corn. U.S.D.A., B.E.P.Q., **E-664.**

Blanchard, R. A., Douglas, W. A., Wene, G. P., and O. B. Wooten, 1951. DDT sprays for control of the corn earworm and the budworm in sweet corn. U.S.D.A., B.E.P.Q., **E-780.** (rev.)

Blanchard, R. A., and W. A. Douglas. 1953. The corn earworm as an enemy of field corn in the eastern states. U.S.D.A., Farm. Bul. **1651** (rev.)

Ditman, L. P. 1950. Control of corn earworm and other pests of corn. JOUR. ECON. ENT. **43**(2): 191.

Douglas, W. A., and C. E. Smith. 1953. Control of the corn earworm and prevention of infestation of the rice weevil in dent corn with DDT and mineral oil spray. Proc. Assn. Sou. Agri. Workers. p. 115.

Eden, W. G. 1952. Control of corn earworm in sweet corn in Alabama. JOUR. ECON. ENT. **25**(1): 105.

Eden, W. G. 1953. DDT for earworm control in sweet corn. JOUR. ECON. ENT. **46**(2): 359.

Frankenfeld, J. C. 1948. Staining methods for detecting weevil infestation in grain. U.S.D.A., B.E.P.Q., **ET-256.**

Kulash, W. M. 1950. Further tests for earworm control in sweet corn. JOUR. ECON. ENT. **43**(3): 430.

Rutschky, C. W. 1952. Oils and insecticides for earworm control on sweet corn. Pa. State College Prog. Rept. **65.**

Wilson, J. W., Thames, W. H., and N. C. Hayslip. 1952. Corn earworm control—summary and recommendations. The Florida Entomologist **XXXV** (1–2): 57–61.

Insects Associated with Salt Cedar in Southern Arizona[1]

LEMAC HOPKINS and L. A. CARRUTH, *University of Arizona, Tucson*

The salt cedar, or French tamarisk, *Tamarix gallica* L., is a native of the Mediterranean region. It is now naturalized and abundantly established in southern and western United States, particularly along streams and irrigation ditches, from near sea level to elevations of 5000 feet. It is a shrub or small tree, 10 to 15 feet in height, with slender, upright or spreading branches. The scale-like leaves are shed annually in late autumn. It is spread by seeds, grows rapidly, is alkali-tolerant and drought-resistant. The small, pink, clustered flowers occur from March to August.[2]

The salt cedar should not be confused with the athel tamarisk, *Tamarix aphylla* (L.) Karst., also an introduced species, which is planted extensively in southwestern desert areas for windbreaks and as a source of shade.

Observations were made in cooperation with the United States Bureau of Reclamation, to provide information on the identity and activity of insects occurring on salt cedar in southern Arizona. It was sought to determine whether this abundant, water-wasting plant might be afflicted with insect pests sufficiently effective, at least in some areas, to materially limit its growth and spread along streams, canals, and ditches in the vicinity of irrigated agricultural districts. The elimination or suppression of this weed would contribute appreciably toward the more effective use of a limited water supply. Related investigations of the possible value of plant diseases, herbicides, and other agencies in limiting the growth of salt cedars are in progress by other workers.

Surveys were made in southern Arizona, on or near the Gila, Salt, and Colorado Rivers, at intervals between November 1951 and May 1953, particularly near the following points (altitude and mean annual rainfall shown in parentheses): Safford (2900 ft.) (9.73 in.), Sacaton (1280) (9.63), Mesa (1150) (6.60), Buckeye (980) (7.55), Wellton (225) (4.63), and Yuma (110) (3.41). Differences in altitude and climate between these points did not appear to affect the growth of salt cedar or the abundance of insects thereon. Most plants observed were in a healthy condition although in localized areas, having a retreating water table, some apparent stunting was observed. Dead branches were common in some

[1] Arizona Agricultural Experiment Station Technical Paper No. 342.

[2] Little, Elbert L., Jr. 1950. Southwestern trees. A guide to the native species of New Mexico and Arizona. U. S. Department of Agriculture, Agriculture Handbook No. 9, pp. 86–7. The Arizona salt cedars designated above as *Tamarix gallica* L. are referred to as *Tamarix pentandra* Pallas, a very closely related species, in "Arizona Flora," by Thomas H. Kearney and Robert H. Peebles, published in 1951 by the University of California Press.

areas and may have been the result of one or more plant diseases or of previous localized injury from some other cause.

No evidences of insect injury were found which were sufficiently severe and widespread to support any assumption that salt cedar could be materially suppressed in Arizona by native insects alone. The more promising possibilities for control or eradication appear to involve practices other than the encouragement of insect enemies.

The following annotated list, arranged by insect groups, includes species observed on salt cedar during this study. Additional species will doubtless be recorded as further observations are made although it is believed that the present list establishes a general pattern. Insects were identified by the senior author, when possible, and by specialists in the former Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture. No other publication dealing with the insect fauna of this plant in North America is known to the writers.

Order: ORTHOPTERA
Family: LOCUSTIDAE
Aeolopus arizonensis Scudder
Adults on foliage, feeding not observed, Gila Bend (July).
Melanoplus differentialis (Thos). (Differential grasshopper)
Adults feeding on foliage; Buckeye (July).
Schistocerca shoshone (Thos.) (Green bird locust)
Adults feeding on foliage; Hassayampa (July). Nymphs feeding on foliage; Buckeye, Mesa, and Yuma (July).
Schistocerca vaga (Scudder) (Grey bird locust)
Adults feeding on foliage and flower buds; Buckeye (July).
Family: MANTIDAE
Mantid nymphs of an undetermined species were predaceous on nearly all other insects present; Buckeye, Mesa, and Safford (July).
Family: PHASMIDAE
Diapheromera arizonensis (Caudell) (Arizona walkingstick).
Adults on foliage, feeding not observed; Safford (July).
Order: THYSANOPTERA
Family: THRIPIDAE
Frankliniella occidentalis (Perg.) (Western flower thrips).
Nymphs and adults common on flowers; Tempe (May), Safford and Tolleson (July). Thrips of other species, as yet undetermined, were also present.
Order: HEMIPTERA, Suborder: HETEROPTERA
Family: COREIDAE
Mozena sp.
One adult was found feeding on foliage; Hassayampa (July). The feeding tube was completely embedded in the plant tissue and the body was nearly perpendicular to the feeding surface.
Family: LYGAEIDAE
Geocoris sp. (Big-eyed bug)
Adults taken in net sweepings of foliage; Yuma (July). Believed to be predaceous on leafhoppers.
Nysius ericae (Schill.) (False chinch bug)
Adults were found in every area visited during the summer of 1952. Only at Safford was this species sufficiently abundant to cause noticeable damage to salt cedar. On one tree these bugs were so numerous that, when disturbed, they resembled a colony of ants. In this case the terminal foliage was yellow or had already been shed and many branches were either dead or dying. This was the most clear-cut example of severe insect injury to salt cedar observed during this survey.
Family: MIRIDAE
Lygus hesperus Knight and *Lygus lineolaris* (P. uB.) (Lygus bugs)
Adults feeding on tender terminal foliage; relatively rare; Safford (July).
Family: NABIDAE
Nabis ferus L. (A common damsel bug)
Adults taken in net sweepings of foliage; Safford, Mesa, and Yuma (July). Believed to be predaceous on leafhoppers.
Family: PENTATOMIDAE
Brochymena sulcata Van Duzee
Adults on foliage; Safford, Mesa, and Yuma (July). The most common species of stink bug on salt cedar although never found in large numbers.
Chlorochroa ligata (Say) (conchuela)
Newly-hatched nymphs feeding on foliage; Safford (May).
Chlorochroa sayi Stäl (Say stink bug)
Adults occasionally present on foliage; Buckeye, Mesa, and Safford (July).
Family: PYRRHOCORIDAE
Euryopthalmus convivus Stäl (Bordered plant bug)
On limbs, trunk, and blossoms; Mesa and Safford (July); Safford (December).
Family: REDUVIIDAE
Zelus renardii Kolen
Although the most common insect predator on salt cedar at most collecting stations, this species was neither abundant nor rare.
Apiomerus crassipes (F). (Bee assassin)
Adults on blossoms at Mesa (July); predaceous on various species of wasps and bees.
Order: HEMIPTERA, Suborder: HOMOPTERA
Family: APHIDAE
Aphis medicaginis Koch (Cowpea aphid)
Colonies present on foliage at Phoenix (April), and on flower clusters at Safford (May).
Macrosiphum pisi (Harr.) (Pea aphid)
Winged adults, probably migrants, on foliage; Phoenix (April).
Macrosiphum solanifolii (Ashm.) (Potato aphid)
Alate and apterous forms on foliage; Phoenix (April).
Myzus persicae (Sulzer) (Green peach aphid)
All stages (except eggs) numerous on foliage; Phoenix (April).
Family: CICADELLIDAE
Empoasca abrupta DeLong
Adults on foliage; Florence, Sacaton, and Yuma (December).
Homolodisca liturata Ball
Adults on foliage; Safford and Mesa (July).

Opsius stactagallus Feiber
Present at all collecting stations in large numbers. Females were observed oviposting in salt cedars at Safford (December). This leafhopper was the most abundant insect species present on salt cedars. In some areas the trees were extremely sticky with the honeydew of this species.

Family: CICADIDAE
Diceroprocta apache Davis
Adults of this cicada were present on foliage, twigs, and limbs at Buckeye, Mesa, Safford, and Yuma (July). Nymphs were found feeding on roots at Buckeye (July and December) and at Safford (July). Twigs at Safford (July) were killed or severely injured by the egg punctures made by ovipositing females of this species.

Family: CIXIDAE
Oecleus decens Stäl
Adults and nymphs on foliage and twigs; Buckeye, Mesa, and Safford (July). Egg masses on twigs at Buckeye and Mesa (April).

Family: COCCIDAE
Chionaspis etrusca Leonard (Tamarisk scale)
Common on all parts of salt cedar, but especially abundant on medium-sized limbs; Florence, Gila Bend, Mesa, Safford, and Yuma (May, July, December). Growth not apparently affected to any serious extent.

Family: FLATIDAE
Ormenis yumana Ball
Adults on foliage; Buckeye, Florence, Mesa, and Safford (July). Nymphs on twigs and small branches; Buckeye and Mesa (April and May).

Family: PSYLLIDAE
Paratrioza cockerelli (Sulc.) (Potato psyllid)
Adults taken in net sweepings of foliage; Phoenix (April), Buckeye, Mesa, and Safford (May). Nymphs never observed on salt cedar.

Order: CORRODENTIA
Undetermined species found under bark; Safford (July).

Order: NEUROPTERA
Family: CHRYSOPIDAE
Chrysopa sp.
Lacewing larvae and adults were taken in net sweepings of foliage at Buckeye, Mesa, and Yuma (July).

Order: HYMENOPTERA
Family: APIDAE
Apis mellifica L. (Honey bee)
Abundant on blossoms at all collecting stations.

Family: FORMICIDAE
Camponotus sp.
Galleries made by this carpenter ant were observed in limbs of salt cedars at Buckeye (May).

Formica perpilosa Wheeler
Workers of this ant were observed at Safford (May) apparently tending colonies of the cowpea aphid (*A. medicaginis*).

Family: MUTILLIDAE
Males of an undetermined species were present on flowers at Mesa (July).

Family: PSAMMOCHARIDAE
Pepsis chrysothemis Lucas
Adults on flowers; Buckeye, Mesa, and Yuma (July).

Family: SCOLIIDAE
Scolia ardens Smith, *Campsomeris tolteca* Sauss., and *Campsomeris pollinifera* Vier.
Adults of this digger wasp were found on foliage at Buckeye and Mesa (July).

Family: SPHECIDAE
Sphecius speciosus Vier. (Cicada killer)
This large mud-dauber wasp was collected at every location where cicadas, especially *Diceroprocta apache*, were abundant, particularly at Buckeye, Mesa, Safford, and Yuma (July).

Order: COLEOPTERA
Family: BUPRESTIDAE
Chrysobothris strofasciata Lec.
One adult taken in net sweepings of foliage; Buckeye (July).

Family: CHRYSOMELIDAE
Chaetocnema ectypa Horn (Desert corn flea beetle)
Adults numerous on foliage; Safford (May).

Family: COCCINELLIDAE
Chilocorus cacti L.
Larvae, pupae, and adults of this lady beetle were present on salt cedar and were predaceous on the tamarisk scale (*Chionaspis etrusca* Leonard) mentioned above. Buckeye, Safford, and Yuma (May and July).

Hippodamia convergens Guerin (Convergent lady beetle)
This predator was observed at Buckeye, Mesa, Safford, and Yuma (July), but was less abundant than *Chilocorus cacti* L.

Scymnus sp.
Apparently feeding on the tamarisk scale (*C. etrusca*); Buckeye (July).

Family: CURCULIONIDAE
Apion sp.
Adult weevils on foliage, largely associated with seed stalks; Mesa (May), Buckeye, and Yuma (July).

Family: MELYRIDAE
Collops vittatus Say
Adults predaceous on small nymphs of leafhoppers; Buckeye, Safford, and Yuma (July).

Family: RHIPICERIDAE
Sandalus californicus Lac.
An adult observed in soil at roots of salt cedar; Buckeye (July).

Family: SCARABAEIDAE
Cotinus arizonensis Casey
Adults feeding on flowers; Mesa (July).

Ochsosidia arizonica Casey
An adult observed in soil near roots; Buckeye (July). Larvae feeding on roots; Buckeye (May).

Order: LEPIDOPTERA
Family: ARCTIIDAE
Estigmene acraea (Drury) (Salt-marsh caterpillar)
Large larvae feeding on foliage; Mesa and Yuma (December).

Family: PAPILIONIDAE
Papilio rutulus Bdvl.
Adults on flowers; Mesa (July).

Family: NYMPHALIDAE
Basilarchia obsoleta (Edwards)
Adults on flowers; Mesa (July).

Family: PIERIDAE
Colias philodice eurytheme Bdvl. (Alfalfa caterpillar)
Adults on flowers; Mesa and Safford (July).

Order: DIPTERA
Family: ANTHOMYIDAE
Hylemyia cilicrura (Rond). (Seed-corn maggot)
Adult flies abundant on blossoms; Safford (May).

Family: SCIOMYZIDAE
Specimens of unidentified species were found on flowers at Buckeye, Mesa, Safford, and Yuma (July).
Family: TABANIDAE
Tabanus punctifer O.S.
Adults taken in net sweepings of foliage at Buckeye and Safford (July). A pupa was taken in soil under a salt cedar at Safford (July).

ADDENDUM

In a letter from J. K. Holloway, Entomologist of the Insect Identification and Parasite Introduction Section, Entomology Research Branch, Agricultural Research Service, United States Department of Agriculture, Albany, California, concerning his observations on *Tamarix gallica* in Spain during the summer of 1953, he states: "I was unable to note any insects particularly destructive to *Tamarix gallica*. All of the families listed below were about equally abundant with the greatest noticeable effect resulting from the *Phycitidae* and the *Curculionidae*." Mr. Holloway's list follows:

Order: HEMIPTERA, Suborder: HETEROPTERA
Family: MIRIDAE (determinations by R. I. Sailer)
Deraeocoris punctulatus (Puton); Toledo Province (June).
Tuponia tamaricis (Perr.); Toledo Province (June), Huelva and Madrid Provinces (July).
Auchenocrepis minutissima (Rmb.); Madrid Province (July).
Campotylus yersini (M. & R.); Madrid Province (July).
Order: HEMIPTERA, Suborder: HOMOPTERA
Family: CICADELLIDAE (determinations by D. A. Young)
Opsius stactogallus Fieber; Toledo Province (June) (adults and nymphs present); Huelva and Madrid Provinces (July).
Erythroneura tamaricis (Puton); Huelva and Madrid Provinces (July).
Family: CIXIIDAE (determination by D. A. Young)
Hemitropis sp., probably *bipunctata* Fieber; Toledo Province (June); Huelva Province (July).
Order: COLEOPTERA
Family: CURCULIONIDAE (determinations by Rose E. Warner)
Nanophyes sp.; Toledo Province (June).
Nanophyes spp.; Huelva Province (July).
Family: CHRYSOMELIDAE (determination by G. B. Vogt)
Diorhabda elongata Brull; Huelva Province (July).
Order: LEPIDOPTERA
Family: PHYCITIDAE (determination by H. W. Capps)
A species not positively determined, possibly *Salebria* sp.; Toledo Province (June).

Application Schedules for Control of Cotton Insects[1]

R. L. HANNA, *Texas Agricultural Experiment Station, College Station*

Work on the evaluation of early season and late season applications for cotton insect control conducted at this Station since 1946 has been briefly reviewed in a previous article by Hanna & Mistric (1953). Generally, early season applications of insecticides have resulted in earlier fruiting of the cotton but insignificant increases in yield. Attempts to lengthen the 5-day interval between late season applications for boll weevil and bollworm control have not been very successful. The replicated small plat test and the replicated large plat test conducted during 1953 and reported here are a continuation of this work.

SMALL PLAT TEST.—Experiment 1 was designed to compare the effectiveness of two early season applications of insecticides for control of thrips, *Frankliniella tritici* Fitch, three early season applications for control of thrips and boll weevils, *Anthonomus grandis* Boh. and, no early season control; to compare a 5-day interval late season schedule, a 7-day interval late season schedule and no late season treatment; also to test all possible combinations of these early season and late season schedules. This resulted in nine treatment-schedule combinations. There were four replicate plats for each schedule combination, making a total of 36 plats. Each plat was 12 rows wide and 0.1 acre in size. A randomized block plat arrangement was used. Early season applications for thrips control were applied May 29 and June 5 using a 2 per cent dieldrin dust at the rate of 5 pounds per acre. The third early season application for control of thrips and boll weevils was made June 16 using the same formulation at the rate of 12 pounds per acre. Late season applications for control of bollworm, *Heliothis armigera* (Hbn.) were made from July 5 to August 16 with 2.5 per cent dieldrin-5 per cent DDT-40 per cent sulphur at an average rate of 14

[1] Technical contribution No. 1937, Texas Agricultural Experiment Station in cooperation with the Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

Table 1.—Summary of data obtained in experiments 1 and 2, College Station, Texas, 1953.

Treatments		Number of Thrips on 10 Plants	Per Cent Bollworm Injured		Pounds of Seed Cotton per Acre
Early	Late		Squares	Bolls	
Experiment 1[1]					
None	None	12.5	26.5	20.0	1205
None	5 at 7-day intervals	10.2	7.6	5.0	2445
None	7 at 5-day intervals	9.8	8.0	4.9	2645
Two	None	7.4	23.7	16.5	1375
Two	5 at 7-day intervals	5.9	7.5	4.5	2280
Two	7 at 5-day intervals	5.6	6.5	3.8	2688
Three	None	5.8	18.6	14.2	1595
Three	5 at 7-day intervals	3.2	7.3	5.0	2570
Three	7 at 5-day intervals	5.4	6.0	3.8	2728
All (Average)	None	8.6	22.9	16.9	1392
All (Average)	5 at 7-day intervals	6.5	7.5	4.8	2432
All (Average)	7 at 5-day intervals	6.7	6.8	4.2	2687
None	All (Average)	10.8	14.0	10.0	2102
Two	All (Average)	6.3	12.6	8.3	2114
Three	All (Average)	4.5	10.6	7.7	2298
Experiment 2[2]					
None	8 at 5- to 7-day intervals	32.0	3.5	1.9	1671
One	8 at 5- to 7-day intervals	21.9	3.3	1.2	1715
Two	8 at 5- to 7-day intervals	12.1	3.6	1.7	1777
Three	8 at 5- to 7-day intervals	7.7	3.5	1.1	1826

[1] Average of 4 replicates.
[2] Average of 3 replicates.

pounds per acre. Plats treated at 5-day intervals received seven late season applications while those treated at 7-day intervals received only five.

Results of this experiment are shown in table 1. The plats which were given early season applications of insecticides had significantly fewer thrips than those which received no early season treatment. Thrips infestation was not significantly different on those plats which had two early season applications and those that had three. The boll weevil infestation was negligible. On those plats which received no late season control, early season applications had a definite effect on percentages of bollworm infestation. Those plats which received three early applications only, had a significantly lower percentage of injured squares and injured bolls than those plats which received no treatment. Also, those plats that received two early season applications only, had a significantly lower percentage of injured bolls than the control plats. Counts of squares and bolls and bollworm egg counts indicated that these differences are due to heavier fruiting of the early treated plats at the beginning of the bollworm infestation period. With the number of bollworms fairly constant over all of the experiment, the percentage infestation was higher on those plats which had less fruit.

Plats receiving three early season applications yielded significantly more seed cotton than those receiving two early season applications or no early season treatment. Plats treated during the bollworm infestation period yielded approximately twice as much cotton as those that were not. Plats which were treated seven tines at 5-day intervals during this period yielded significantly more than those treated five times at 7-day intervals.

The conditions under which this experiment was conducted made the effectiveness of insecticidal applications in increasing yields easy to demonstrate. Soil fertility and soil moisture were adequate and insect damage was serious. The degree of thrips control obtained by three early season treatments resulted in slightly more fruit during the month of June. This earlier fruit was less susceptible to bollworm damage because of its maturity during the bollworm infestation period. Consequently there was a small but significant increase in yield due to three early season applications of insecticides. Slight differences in the degree of bollworm con-

trol which were not statistically significant because of sampling variation caused the yield to be significantly greater on those plats treated every five days for bollworm control than on those which were treated every seven days. Adequate moisture supply prevented the loss of these yield margins by the shedding of fruit.

LARGE PLAT TEST.—Experiment 2 was a randomized block experiment designed to test the effectiveness of one, two, and three early season applications of insecticides on a larger plat basis. The plats were 48 rows wide and 3 acres in size. There were three blocks with four plats in each block. One plat in each block received an early season application of toxaphene on June 9, June 16, and June 23. A second plat in each block was treated only on the last two dates and a third received only the June 23 application. The remaining plat in each block was untreated during the early season period. The first two applications were made at the rate of 1 pound of toxaphene per acre. The third was increased to 1.5 pounds of toxaphene per acre to give better control of boll weevils. Since the cotton in this field was not planted until late May, the June 9 application was made when most of the cotton plants were in the 2-leaf stage.

All plats were treated alike during the late season, bollworm infestation period. The entire field was treated as a unit, by airplane. There were eight applications of insecticides for bollworm and aphid control from July 6 to August 23. Five of these were made with toxaphene-DDT (2-1) spray at the rate of 3 pounds active ingredient per acre. One application of 3 per cent gamma iosmer of BHC-5 per cent DDT-40 per cent sulphur and two applications of 3 per cent gamma isomer of BHC-10 per cent DDT-40 per cent sulphur were made at the rate of 17 pounds per acre.

Results of this test are also shown in table 1. Three early season applications significantly reduced the thrips population for the early season treatment period. Counts of fruit forms during July indicated a slightly earlier fruiting for those plats which received early season treatment but the amount of variation in these counts kept these differences from being statistically significant. There were no significant differences in yield resulting from the early season applications of insecticides.

SUMMARY.—A small plat test of factorial design conducted to evaluate early season and late season application schedules for cotton insect control showed a significantly lower thrips population and a higher yield as a result of three early season applications of insecticide. Seven late season applications at 5-day intervals resulted in significantly higher yield than five late season applications at 7-day intervals. A replicated large plat test designed to test the relative effectiveness of one, two, and three early season applications of insecticides showed a significant reduction of thrips numbers due to three early season applications of insecticides but no significant increase in yield.

LITERATURE CITED

Hanna, R. L., and W. J. Mistric, Jr. 1953. Effect of Different Schedules for Control of Cotton Insects. JOUR. ECON. ENT. **46**(4): 641.

Malathion and Malathion-Parathion Sprays for Control of the Soft Scale on Citrus in California[1]

H. S. ELMER and W. H. EWART, *University of California Citrus Experiment Station, Riverside California*

In certain California citrus groves outbreaks of the soft scale, *Coccus hesperidum* L., have followed applications of parathion for the control of other pests (Elmer *et al.* 1951). These outbreaks, which have occurred in only relatively few of the groves receiving parathion treatments, are apparently the result of the adverse effect of parathion on entomophagous insects, principally *Metaphycus leuteolus* (Timb.), which normally keeps populations of soft scale at a low level (Bartlett & Ewart 1951).

[1] Paper No. 823, University of California Citrus Experiment Station, Riverside, California.

Table 1.—Reduction of soft scale populations on citrus trees with sprays containing malathion or combinations of malathion and parathion.[1]

Treatment (Lbs. 25 Per Cent Wettable Powder per 100 Gallons)			Posttreatment Scale Population Counts				
			Average No. Live Scales per Leaf After				
			1 Month		2 to 4 Months		Average Per Cent Reduction
Malathion		Parathion	Treated	Check	Treated	Check	
0.5		—	1.7	6.5	1.1	6.4	78.3
0.5	+	0.5	1.0	5.5	1.0	6.7	83.6
0.5	+	1.0	1.4	8.0	0.8	8.2	86.4
0.5	+	1.5	0.6	6.3	1.5	8.9	86.2
1.0		—	2.0	10.0	1.5	9.7	82.2
1.0	+	0.5	0.8	7.7	0.7	9.9	91.5
1.0	+	1.0	0.3	7.5	0.9	7.3	91.9
1.0	+	1.5	0.4	6.9	0.8	8.5	92.2
1.5		—	1.1	9.8	0.9	7.5	88.4
1.5	+	0.5	0.4	8.0	0.4	6.3	94.4
1.5	+	1.0	0.2	6.6	0.6	4.8	93.0
1.5	+	1.5	0.2	6.2	0.7	6.4	92.8
—		2.0	3.9	6.3	3.5	6.0	39.8

[1] Applications were made at the rate of 2250 gallons per acre with hand-operated guns from a high-pressure sprayer.

In some parathion-treated groves it may be several months before the parasites are able to control high populations of the soft scale, and during this time the trees may become so devitalized that serious reductions in fruit yield result (Ewart & Elmer 1953). Since parathion is highly effective for the control of several California citrus pests (Carman & Ewart 1950) and is widely used commercially for control of the California red scale, *Aonidiella aurantii* (Mask.), yellow scale, *A. citrinia* (Coq.), and citricola scale, *Coccus pseudomagnoliarum* (Kuw.), its use is desirable. A suitable insecticidal control is therefore needed for occasional soft scale outbreaks.

Laboratory and field studies of a large number of insecticides in 1949, 1950, and 1951 indicated that malathion was a promising material for the control of soft scale. Further studies were conducted in 1952 and 1953 with the objective of developing information on the use of malathion alone and in combination with parathion for the combined control of soft scale and one or more of the scale species named above. It is the purpose of this report to summarize the results of these studies as they pertain to soft scale.

MATERIALS AND METHODS.—Treatments consisting of 0.5, 1.0, and 1.5 pounds of 25 per cent malathion wettable powder used alone and in combination with 0.5, 1.0, and 1.5 pounds of 25 per cent parathion wettable powder per 100 gallons of spray were used in replicated plots in four citrus groves. A standard treatment of 2.0 pounds of 25 per cent parathion wettable powder per 100 gallons of spray was also applied in each grove.

All treatments were applied as thorough-coverage sprays at the rate of approximately 2250 gallons per acre (90 trees), using hand-operated spray guns from conventional high-pressure equipment. Applications were made during the period from November to February, inclusive, when parasite activity was at a low level. Treatments were evaluated by comparing posttreatment scale populations of treated plots with those of adjacent untreated plots having comparable pretreatment populations. The results are expressed as average per cent reduction of scale population, a figure computed from the posttreatment counts in the treated and the adjacent untreated plots.

RESULTS.—Results (Table 1) show that at dosages of 0.5, 1.0, and 1.5 pounds of 25 per cent malathion wettable powder per 100 gallons of spray the reduction of soft scale averaged 78.3, 82.2, and 88.4 per cent, respectively. When the above-listed malathion dosages were combined with 0.5 pound of 25 per cent parathion wettable powder per 100 gallons of spray, the reduction averaged 83.6 91.5, and 94.4 per cent, respectively; with 1.0 pound of parathion 86.4, 91.9, and 93.0, respectively; and with 1.5 pounds of para-

thion 86.2, 92.2, and 92.8, respectively. It is thus apparent that the effectiveness of malathion sprays increased as the dosage of malathion was increased and that sprays containing mixtures of malathion and parathion were more effective than corresponding sprays containing malathion alone. The effectiveness of the combination sprays also increased as the dosage of malathion was increased but was not significantly affected by increasing the dosage of parathion.

The standard treatment of 2.0 pounds of 25 per cent parathion wettable powder per 100 gallons of water resulted in an average reduction of 39.8 per cent. This reduction was mainly due to the initial mortality of small and immature stages of soft scale and clearly shows the relative ineffectiveness of this treatment.

Population counts were discontinued 4 months after the treatments were applied because parasites had become well established in many of the plots. Five months after applications the soft scale populations were reduced by parasites to a very low level in all plots, including those treated with the standard parathion treatment.

A combination of 1.5 pounds of 25 per cent malathion wettable powder and 0.5 pound of 25 per cent parathion wettable powder was the most effective spray for the control of soft scale.

SUMMARY.—Sprays containing malathion alone and in combination with parathion were applied with hand-operated guns from conventional high-pressure equipment at the rate of approximately 2250 gallons per acre to citrus groves for the control of the soft scale, *Coccus hesperidum* L. Dosages of 0.5, 1.0, and 1.5 pounds of 25 per cent malathion wettable powder alone and in combination with 0.5, 1.0, and 1.5 pounds of 25 per cent parathion wettable powder per 100 gallons of spray were applied to four different groves during the winter months when there was very little parasite activity. The effectiveness of the malathion sprays increased as the dosage was increased, and sprays containing mixtures of malathion and parathion were more effective than corresponding sprays containing malathion alone.

The most effective treatment was a spray containing 1.5 pounds of 25 per cent malathion wettable powder plus 0.5 pound of 25 per cent parathion wettable powder per 100 gallons.

LITERATURE CITED

Bartlett, Blair, and W. H. Ewart. 1951. Effect of parathion on parasites of *Coccus hesperidum*. JOUR. ECON. ENT. **44**: 344–7.

Carman, G. E., and W. H. Ewart. 1950. Present status of information on parathion for the control of several pests on citrus in California. Univ. of Calif. Citrus Expt. Sta., Div. of Ent., News Letter No. **48**.

Elmer, H. S., W. H. Ewart, and G. E. Carman. 1951. Abnormal increase of *Coccus hesperidum* in citrus groves treated with parathion. JOUR. ECON. ENT. **44**: 593–7.

Ewart, W. H., and H. S. Elmer. 1953. Effect of unarmored scales on citrus production. Calif. Citrog. **38**: 352.

An Adaptation of Commercial Shearing Equipment for Sampling Range Vegetation

E. J. HINMAN, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

In 1953 an enlarged program of sampling rangeland vegetation treated with insecticides for use in residue analyses emphasized the need for faster and more efficient methods than had previously been used for harvesting the samples. Commercial sheep-shearing equipment was found to be excellent for clipping range vegetation, especially short varieties such as blue grama and *Carex*. In timed tests an operator, using mechanical shearers with the attachment to be described, clipped a measured quadrate of blue grama in one-eighth the time it took him to clip a similar quadrate with hand shears.

A commercial shearer was adapted as a clipper for harvesting the grass samples. It was electrically driven and required 110 volts. The power was supplied by a

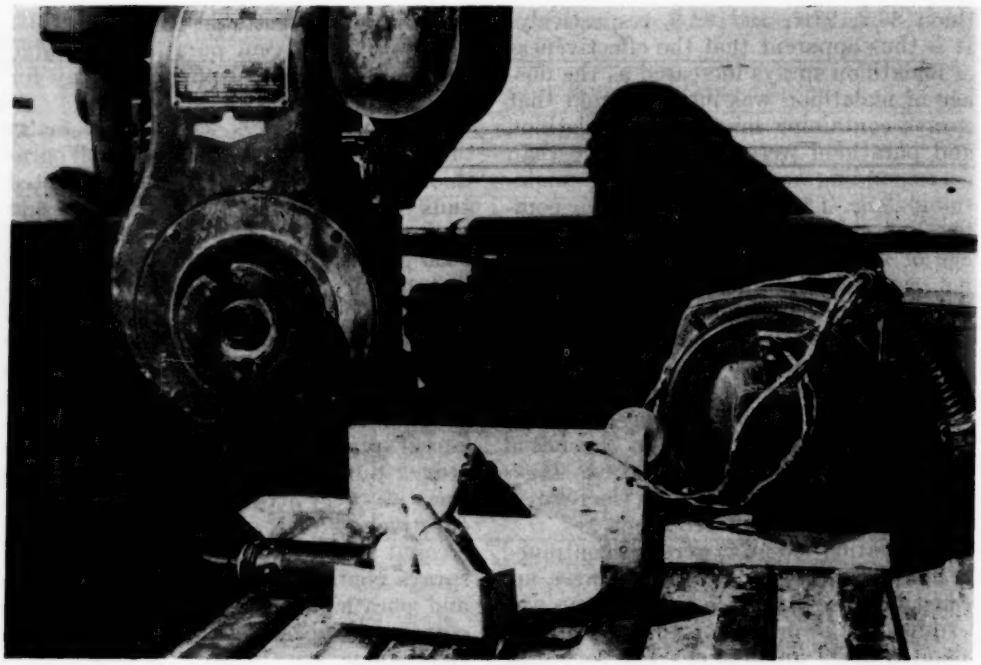


FIG. 1.—Gasoline-driven alternator in a pickup truck bed.

semi-portable, gasoline-driven alternator mounted on a pickup truck (Fig. 1). A 75-foot extension cord allowed adequate freedom for sampling several subareas without moving the truck.

For harvesting tall grass the clipper was used without attachments. As much standing grass as could be conveniently gathered in one hand was held and cut off at the desired height above the ground. This left a bundle of grass in the hand ready for cutting into short pieces with the clipper (Fig. 2). As the short pieces were cut off, they were allowed to fall into a cardboard carton. When the vegetation was short and scattered, handfuls could not be gathered, and something was needed to catch it as it fell from the clipper. To provide for such situations a catching attachment was made as herein described.

CONSTRUCTION OF CATCHING ATTACHMENT.—The catching attachment was made from a piece of 20-gage sheet aluminum $9\frac{1}{4}$ by 10 inches. Figure 3 gives the outlines and dimensions for laying out, cutting, and bending the sheet. The four cuts along the solid lines to the four points marked "A" end in 1/32-inch drilled holes, which prevent the metal from cracking from the end of the cut when the bending is done. The cross-hatched area at the left was sunk about $\frac{1}{8}$ inch to clear a projection on the machine. This was done by positioning the material over the jaws of a vise that were opened $\frac{3}{4}$ inch and sinking the desired area with a ball peen hammer. When the side and end members were bent upward at right angles along the dashed lines marked "bend up," the $\frac{3}{4}$-inch tabs at the ends of the right side lapped over the end uprights. These were riveted in place. The tab marked "bend down" near the center of the diagram was bent down and rolled as shown in figure 4. This tab, with the runner-like front projection of the left

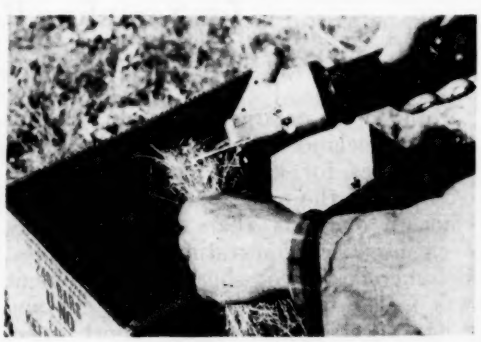


FIG. 2.—Chopping vegetation into short lengths.

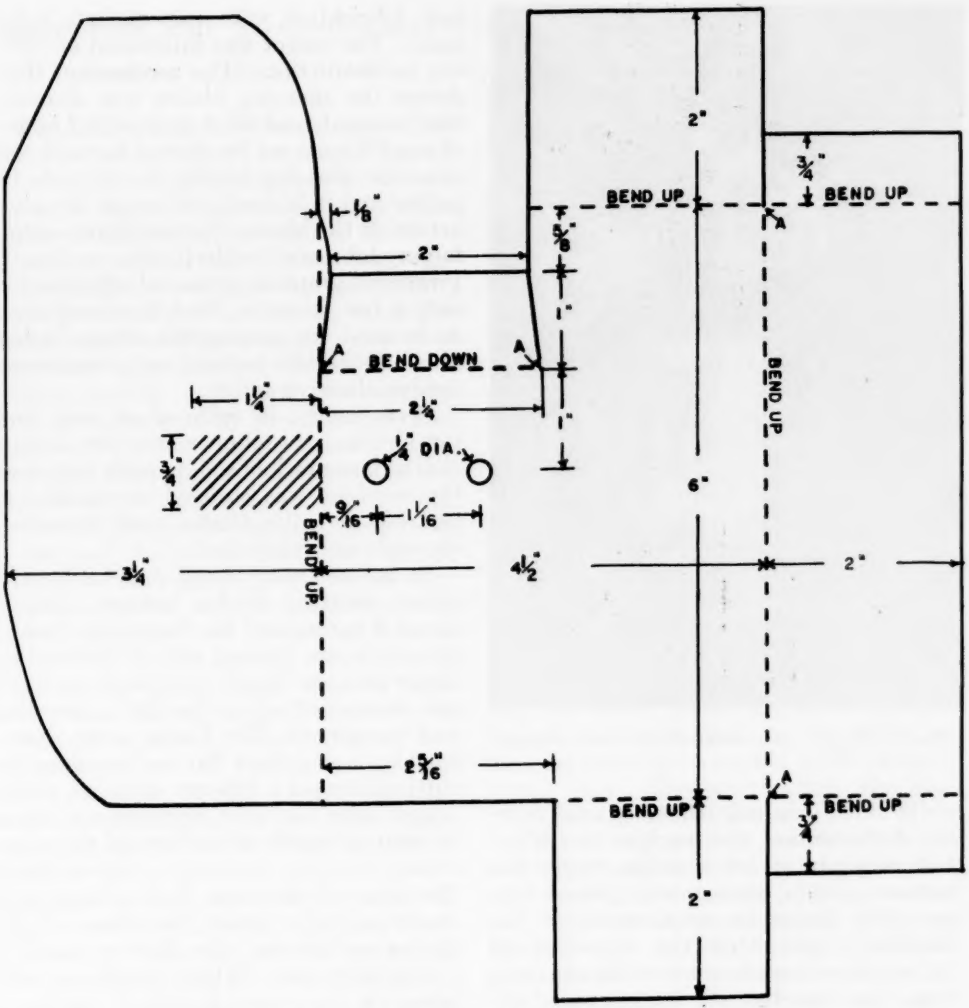


FIG. 3.—Layout for catching attachment.

side, helps to keep the cutting blades out of the soil.

The attachment is held to the clipper

FIG. 4.—Attachment assembled on clipping machine.

by the two screws, which also hold the lower blade in place. The $\frac{1}{4}$-inch holes allow slight movement for accurate positioning of the attachment (Fig. 5). The shape of the trimmed top corners and the curved runner on the bottom front of the side is not critical. They were trimmed free-hand after the attachment was otherwise completed. Care should be taken when mounting the attachment to be sure that the mounting screws are tight.

USE OF THE CLIPPER WITH THE ATTACHMENT.—For sampling very short vegetation it was most convenient to clip rectangular quadrates. A quadrate width of 18 or 24 inches provided the most effective clipping stroke. The clipper was moved rapidly at clipping height the full

FIG. 5.—Proper attachment of catcher to clipper.

width of the quadrate; then, without slowing of the motion, the machine was lifted and swung in an arc so as to empty the contents into a conveniently placed carton. Any hesitation or stopping of the movement permitted the vibration of the machine to shake some of the contents from the attachment. Each swath adjoined the previous one, and the clipping proceeded from right to left along the quadrate. The handle of the clipper was held low and approximately parallel to the ground.

When suitable amounts of vegetation accumulated in the carton, it was cut to the required shorter lengths, a handful at a time. Cutting of short vegetation was done with the attachment in place.

CARE AND MAINTENANCE OF THE MACHINE.—Since this use of the shearer as a grass clipper was not intended by the manufacturer, the instructions for its care and lubrication were not entirely adequate. The motor was lubricated according to instructions. The mechanism that drives the shearing blades was dismantled, cleaned, and oiled after each 2 hours of use. Oil must not be allowed to run down onto the shearing blades, for it tends to gather and hold dust and hasten abrasive action on the blades. No completely satisfactory lubricant for the blades was found. Powdered graphite remained effective for only a few minutes. Stick lubricant such as is used on automobile doors lasted about 30 minutes and did not promote excessive abrasive action.

Occasionally, in spite of all care and precautions, the clipper was run into a clod or hummock of soil. In such instances the machine was stopped as quickly as possible and the blades were removed, cleaned, and lubricated.

In rather dusty range vegetation the upper shearing blades became dull in about 2 hours, and the lower ones lasted about 4 hours. Several sets of blades (two upper and one lower) were kept on hand and sharpened when the day's sampling was completed. The blades were sharpened by laying them flat and grinding the cutting face on a 220-grit abrasive stone. A new stone was used, and care was taken to wear all parts of the face of the stone evenly, in order to avoid a depression at the center of the stone. Such a depression would slightly round the faces of the blades and destroy the shearing contact.

PRECAUTIONS.—When vegetation was being cut into short lengths, it appeared rather hazardous to have the whirring cutting head so close to and occasionally touching the hand that held the vegetation. Careful tests showed that the only part of a man's hand that can enter the comb of the clipper far enough to be cut was the web between the thumb and first finger, and that such injury was avoided if the cutting movement of the clipper was in a direction from the wrist toward the hand. The greatest hazard was puncture wounds caused by the fairly sharp teeth of the comb. Reasonable alertness and care avoided this type of injury.

Biological and Toxicological Studies of the Little House Fly[1]

LAWRENCE L. LEWALLEN,[2] *University of California Citrus Experiment Station, Riverside*

The little house fly, *Fannia canicularis* (L.), is frequently of economic importance in places where poultry and livestock are kept. Large numbers of this fly often appear in the spring, breeding in the feces of various animals and in decaying vegetable matter. According to Sampson (1950), this fly sometimes attains an economic status from breeding in waste products of canneries. Accounts of intestinal and urinary myiasis in man by this species have been reported by Hewitt (1912) and James (1948). The role this species might play as a disseminator of disease is not clear from the literature.

Since little or nothing has been done in the way of rearing this fly in the laboratory or making toxicity studies of it with insecticides, such investigations have seemed desirable, and in view of increasing interest in the species, especially by poultrymen, the present studies were undertaken. In order to gain a more comprehensive understanding of this species, observations on the biology and habits were also made to supplement and augment observations made by earlier workers, particularly Hewitt (1910) and Lesne (1921).

An extremely heavy infestation of the little house fly occurred at a chicken ranch in Hemet, California, in the spring of 1954, practically the entire fly population consisting of this species. Adult flies and larvae were therefore collected at this ranch and brought into the laboratory to initiate a stock colony for laboratory rearing studies.

REARING PROCEDURE.—Little house fly adults were held in a 12-inch-square screened cage having a plywood bottom and front. Access to the interior of the cage for feeding of the flies and removal of eggs deposited on the oviposition medium was provided by a muslin cloth sleeve 6 inches in diameter and 16 inches long attached to a circular opening in the front of the cage. A cotton pad thoroughly saturated with a 20 per cent sugar solution and placed in a cardboard sputum cup served as a source of food. Flies confined to the rearing cages fed very readily on this sugar solution, regurgitating and depositing specks in much the same manner as the house fly, *Musca domestica* L.

Another food source that served also as oviposition medium consisted of a cotton pad thoroughly saturated with a solution of protein hydrolysate[3] held in a deep 9-cm. petri dish. The protein hydrolysate solution was prepared by dissolving 2.25 grams of protein hydrolysate granules in 50 ml. of water. Two-day-old pads proved to be more attractive for oviposition than freshly prepared ones.

When newly emerged flies were introduced into the rearing cages, the preoviposition period lasted from 4 to 5 days. Pads containing from 200 to 300 eggs were removed from the petri dish and placed on top of a rearing medium contained in a 1-gallon glass mayonnaise jar. Usually, two pads were placed in each jar. The jar top was covered with a muslin square held in place by two rubber bands. Newly hatched larvae fed at first on the protein hydrolysate contained in the pads; as they became older, usually in the second-instar stage, they moved into the surrounding medium in the jar.

The rearing medium consisted of the following well-mixed ingredients: 12.5 ml. concentrated diamalt, 598 ml. water, 30 grams dried brewer's yeast, 112 grams finely ground laboratory chow,[4] and 225 grams milled red wheat bran.

Mature larvae were allowed to pupate in the jar around the margin and on top of the medium. At the end of the pupal stage, adult flies emerged in the same jar and were either taken off into a holding cage for aging and testing or transferred into the rearing cage.

Although fairly large numbers of flies were obtained by this method, it was not entirely satisfactory from the standpoint of continuous rearing. In the course of these studies, three generations of flies were reared with a decreasing number of adults in each succeeding generation.

[1] Paper No. 819, University of California Citrus Experiment Station, Riverside, California.

[2] The author wishes to express his appreciation to Dr. Ralph B. March for encouragement and suggestions throughout the course of this study; to Mr. Lloyd E. Vincent, who located the source of material for rearing experiments; and to Mr. Harry Orme, poultryman, who cooperated in the project.

[3] MRT; Marvin R. Thompson, Inc., Stamford, Conn.

[4] Purina Laboratory Chow (micro-mixed); manufactured by Ralston Purina Company, St. Louis, Missouri.

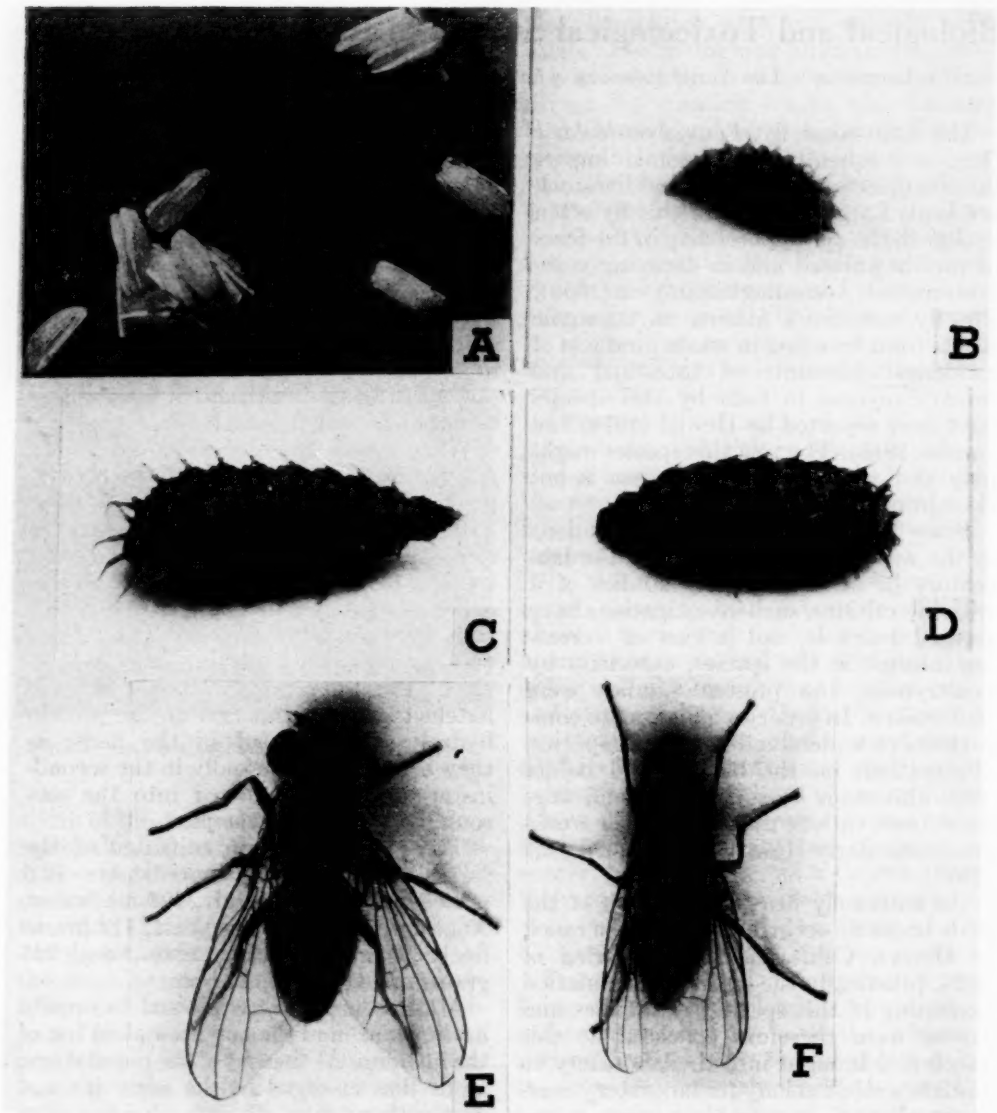


FIG. 1.—The little house fly, *Fannia canicularis* (L.): (A) eggs (×15); (B) second-instar larva (×10); (C) mature larva (×10); (D) pupa (×10); (E) adult female (×10); (F) adult male (×8). Photographed by Kenneth L. Middleham from living specimens. The wings have been spread slightly in E and F.

However, a sufficient number of flies were obtained to provide insects of a known age and reared under uniform conditions for toxicity tests.

DESCRIPTION OF STAGES AND LIFE CYCLE.—The egg of the little house fly is white, elongate (about 2 mm. long), and encased in a sheath which is ribbed below and extends along each side of the egg as a flattened winglike process with a reticulated area on top between the processes (Fig. 1A). The eggs are usually deposited side by side with the reticulated area on top, but clusters may occur when oviposition is heavy. According to Lesne (1921), the winglike processes make the egg float when deposited in a liquid medium. It required from 36 to 48 hours for the eggs to hatch when held at approximately 80° F. and 65 per cent relative humidity. This temperature and humidity were maintained throughout the rearing cycle.

The larval stage lasts from 8 to 10 days.

In this stage the most striking characteristics are the spiny processes along the sides and top of the body. The body is somewhat compressed dorsoventrally, but in general outline is muscoid in shape. The various instars may be described as follows:

First Instar. Translucent, white, with only tip of mouth hooks black; 1.5 mm. long; duration, 24 hours.

Second Instar. Translucent, white; middle portion of cephalo-pharyngeal skeleton black, as are the mouth hooks; 3 mm. long; duration, 24 hours (Fig. 1B).

Third Instar. Light-brownish color; cephalo-pharyngeal skeleton entirely black; mature larva 6 to 7 mm. long; duration of this stage, 5 to 7 days (Fig. 1C).

The pupal stage is characterized merely as a quiescent larva that has ceased feeding, drawn in the cephalic region, and become somewhat shortened, with the integument hardened and dark (Fig. 1D). The pupal stage lasts from 8 to 12 days.

The adult little house fly looks very similar to the ordinary house fly except that it is much smaller, measuring only 5 to 6 mm. in length (Figs. 1E, 1F). A rather complete description of the adult has been given by Hewitt (1910). Three-day-old adults reared in the laboratory and fed on a 20 per cent sugar solution weighed on the average, 6.89 mg. per male and 7.35 mg. per female.

HABITS.—The male little house fly is most frequently observed within buildings, flying about aimlessly in the middle of the room, or else in some shaded area outside, such as the shade of a tree or building. In forming the flight pattern the male performs some amazing antics, sometimes hovering, sometimes turning back sharply in a zigzag fashion. Flight is often sustained for long periods of time.

Apparently, the female does not fly so much as the male, and when she does it is for a much shorter period. When flying from one point to another the female flies in a somewhat zigzag fashion, but goes more or less directly to the other point. Both females and males are frequently found resting on weeds, tree trunks, or branches, or against the sides of buildings. The resting position of the male is very often head downward.

Since this fly rests much more readily on walls and ceilings of farm buildings than the hovering flight pattern of the male would indicate, it seems probable that residual insecticides might be effectively employed for control of this species.

In areas where high summer temperatures prevail, this fly tends to disappear during the summer, being present in great numbers only during the cooler spring months. In areas having cool summers it is possible that this species might be found up to autumn. Nieschulz (1935), in laboratory experiments, found that the little house fly became active at a lower temperature than the house fly (40.1° F. for *Fannia canicularis* and 44° F. for *Musca domestica*) and that it succumbed to heat paralysis at a lower temperature (105.5° F. for *F. canicularis* and 115.7° F. for *M. domestica*). In many localities this may be a factor in the predominance of the little house fly in the spring and of the house fly later when temperatures are higher.

TOXICITY STUDIES.—Standard procedures for topical application of cubic millimeter drops (March & Metcalf 1949) were used in conducting toxicity tests with little house fly adults. In preliminary trials, a cubic millimeter drop of acetone was applied topically to the thoracic notum of each individual fly without producing any mortality after 24 hours, when the flies were held at a temperature of 60° F., thus indicating that the solvent would not interfere in the mortality counts. In applying the toxicants, various concentrations of insecticides were used as weight/volume solutions in acetone.

Carbon dioxide gas was used to anesthetize the adult flies. Preliminary trials indicated that 15 to 20 per cent mortality resulted when the flies were anesthetized for 1 hour at room temperature. At 45 minutes, no mortality occurred; all tests were therefore completed within this time limit. Three- and four-day-old sugar-solution-fed flies of both sexes were treated, 20 flies being treated with each concentration of a given insecticide. Cylindrical, pint ice-cream cartons in which the ends had been replaced by wire screen were used for holding the flies after treatment. Each carton was supplied with a short piece of dental roll thoroughly soaked in 40 per cent sugar solution to serve as food during the holding period. The flies were held at 60° F., the mortality

Table 1.—Measured drop tests applied topically showing comparative 24-hour LD_{50}'s[1] in micrograms per fly for the susceptible female house fly, and male and female little house fly.

Compound	Micrograms per Fly		
	House Fly (female)	Little House Fly (female)	Little House Fly (male)
DDT	0.033	2.80	1.30
Methoxychlor	0.068	0.14	0.12
Lindane	0.010	0.76	0.39
Dieldrin	0.031	0.003	0.0026
Pyrethrins	1.00	0.24	0.44
Malathion	0.56	0.10	0.06
Diazinon	0.092	0.098	0.054
Chlorthion[2]	0.33	0.035	0.022

[1] The amount of toxicant required to kill 50 per cent of the flies treated.
[2] 0,0-dimethyl,0-4-nitro-3-chlorophenyl thionophosphate; Farbenfabriken Bayer, Leverkusen, Germany.

counts being made 24 hours later.

Since only a limited number of flies were available for toxicity studies, it was decided that more useful information could be gained by obtaining approximate LD_{50} values for a number of compounds rather than by obtaining more precise LD_{50} values for a few compounds; therefore, the tests were not replicated.

Dosage in micrograms per fly was plotted against percentage mortality on log-probit paper. The straight-line curve was drawn by inspection, and the LD_{50} value was determined from the curve. The results of tests conducted with eight insecticides are given in table 1. In each case, except with pyrethrins, the male was more susceptible than the female.

Of particular interest is the high degree of tolerance shown by the little house fly to DDT and lindane (table 1). This may indicate that this species has developed resistance to these compounds, although it was not possible to verify this because no known susceptible strain was available for comparison. A comparison of LD_{50} values of the female little house fly with those of the susceptible female house fly, on the basis of micrograms of insecticide per fly, showed that the little house fly was 85 times more tolerant to DDT, 76 times more tolerant to lindane, and 2 times more tolerant to methoxychlor. A comparison on a weight/fly basis would further increase this tolerance, since the little house fly weighs one-third less than the house fly. It is somewhat surprising that such a high degree of susceptibility was shown for dieldrin if resistance to chlorinated hydrocarbon insecticides is indicated by the results obtained with DDT and lindane. Compared with the susceptible female house fly, the little house fly was 10 times more susceptible to dieldrin. Pyrethrins proved to be about 4 times more toxic to the little house fly than to the house fly.

Organo-phosphorous insecticides that are effective toxicants against insecticide-resistant house flies are also effective against the little house fly. The compounds of this group that were tested on the little house fly in the order of decreasing toxicity are as follows: *Chlorthion*, Diazinon, and malathion. The degree of difference in toxicity between these compounds is slight and all three would likely be suitable for control measures.

Summary.—A laboratory method of rearing the little house fly, *Fannia canicularis* (L.), is reported along with observations on the biology at a temperature of 80° F. and 65 per cent humidity. Under these conditions, the egg stage lasted from 36 to 48 hours, the larval stage from 8 to 10 days, and the pupal stage from 8 to 12 days. The preoviposition period for the female lasted from 4 to 5 days. The complete cycle from egg to egg required from 24 to 29 days.

Toxicity studies revealed that the female little house fly was 85 times more tolerant to DDT, 76 times more tolerant to lindane, and 2 times more tolerant to methoxychlor than the susceptible house fly. The little house fly was 10 times more susceptible to dieldrin than the house fly. Pyrethrins proved to be 4 times more toxic to the little house fly than to the house fly.

Organo-phosphorous insecticides that were tested against the little house fly listed in the order of decreasing toxicity are as follows: *Chlorthion*, Diazinon, and malathion.

Literature Cited

Hewitt, C. Gordon. 1910. The house-fly. University Press, Manchester, England.
Hewitt, C. Gordon. 1912. *Fannia* (*Homolomyia*) *canicularis* Linn. and *F. scalaris* Fab. an account of

the bionomics and the larvae of the flies and their relation to myiasis of the intestinal and urinary tracts. Parasitology 5(3): 161–74.
James, Maurice T. 1948. The flies that cause myiasis in man. U. S. Dept. Agr. Misc. Pub. 631: 135–7.
Lesne, P. 1921. La faune entomologique des fosses d'aisances de la région parisienne. Les *Fannia* scatophages. Paris Mus. d'Hist. Nat. Bul. 27: 53–9.
March, R. B., and Metcalf, R. L. 1949. Laboratory and field studies of DDT resistant houseflies in southern California. Calif. State Dept. Agr. Bul. 38: 93–101
Nieschulz, Otto. 1935. Über die Temperaturabhängigheit der Aktivität und die Vorzungstemperatur von *Musca domestica* und *Fannia canicularis*. Zool. Anz. 110(9/10): 225–33.
Sampson, W. W. 1950. Control of insects in the cannery. Pest Control 18(5): 18–28.

Control of the Pepper Weevil

JOHN C. ELMORE and ROY E. CAMPBELL, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The pepper weevil, *Anthonomus eugenii* Cano, is a serious pest of peppers in the Southern States from California to Georgia and Florida. It has been in California since 1923 (Campbell 1924), and has caused very heavy losses to the pepper industry, particularly following mild winters (Elmore *et al.* 1934). By 1928 weevil infestations were common in all the counties of southern California from Ventura south, with the probable exception of Imperial County. In 1940 it occurred as far north as Santa Barbara.

The pepper weevil does not hibernate in the true sense, but is alternately active and inactive during the winter months, in accordance with prevailing temperatures, provided its host plants survive. In hibernation cage tests Elmore *et al.* (1934) showed that the pepper weevil could not survive more than 39 days on nonhost plants, but could live for 5 months on natural host plants. Mild winters are favorable and cold winters unfavorable to weevil survival.

Because of unfavorable winter weather since 1946 in southern California, as well as a general practice of eliminating weevil host plants in and near pepper fields, the pepper weevil has gradually retreated southward. At present it is found no farther north than just below San Clemente, in northern San Diego County. In 1952 and 1953 only light and comparatively late infestations were encountered near San Clemente, but infestations were early and heavy in the San Luis Rey Valley farther south.

A similar pattern of advance and retreat has occurred in the Rio Grande Valley of New Mexico. At one time the pepper weevil was reported damaging peppers as far north as Socorro. At other times none could be found in any of the pepper-growing areas as far south as La Mesa, near El Paso, Texas.

Natural enemies have not been important in checking pepper weevil abundance, probably because its immature stages are well protected inside pepper pods.

After the pepper weevil was discovered in California and until DDT was available, there was no entirely satisfactory chemical control. Calcium arsenate and cryolite had been used with some success, but cage tests (Campbell 1944) indicated that complete mortality could not be expected when adult weevils were placed on plants treated with either of these materials. Calcium arsenate was objectionable because arsenic was usually absorbed by the pod stems and could not be removed. DDT was found to be the most effective material tested and has been in common use since 1945.

Even when DDT is used, the pepper weevil is very difficult to control if a heavy infestation has already become established. This is particularly true if applications are not made at sufficiently frequent intervals. All life stages of the pepper weevil except the adult are protected from insecticides. Consequently adult weevils are able to complete development inside the pod and emerge 3 to 4 weeks after eggs are laid. Failure to cover the plants thoroughly with DDT or improper timing of applications may permit the survivors of each succeeding generation of adults to lay eggs in enough pods to cause considerable damage.

To protect the crop an insecticide must kill practically all adult weevils in a short time after it is applied and must remain effective between applications. In practice, three applications of DDT at 7-day

Table 1.—Effectiveness of various insecticide dusts against the pepper weevil. 1947.

Dust (Per Cent of Active Ingredient)	Number of Weevils Used[1]	Number of Weevils Dead After—				Total Per Cent Mortality
		1 Day	2 Days	3 Days	4 Days	
DDT 10	70	40	68	69	69	98
Chlordane 10	70	55	65	68	68	97
BHC (gamma isomer) 2	70	40	65	68	68	97
Parathion 1	30	16	25	29	29	97
Toxaphene 10	70	26	56	59	63	90
Lindane 1	40	12	30	34	35	88
BHC (gamma isomer) 1	70	29	48	56	57	82
Untreated check	70	4	5	6	6	8.6

[1] Weevils put into cages immediately after application of dust

intervals followed by two applications 10 days apart have been successful in controlling heavy infestations. Farmers unfamiliar with pepper weevil habits fail to recognize the necessity of such an intensive dusting program, and are usually disappointed with the results they obtain.

CAGE TESTS.—In 1947 cage tests against the pepper weevil were made at Alhambra, Calif., comparing DDT and other new insecticides when applied as dusts. The experiments were arranged to determine how rapidly the materials would kill weevils and how long they would protect the pepper plants. Individual pepper plants were used as test units, and each treatment was replicated three or four times. The methods were those described by Elmore (1933) and Campbell (1944), consisting essentially in caging dusted plants individually with 10 weevils. In one experiment weevils were introduced immediately after the insecticide application, and in another immediately and after 5 and 10 days. The results of these tests are shown in tables 1 and 2.

Table 2.—Per cent mortality of pepper weevil adults caged for 4 days on pepper plants immediately, 5 days, and 10 days after the plants were dusted with insecticides. 1947.

Dust (Per Cent of Active Ingredient)	Immediately	After 5 Days	After 10 Days
DDT 10	100	100	80
BHC (gamma isomer) 2	100	100	80
Toxaphene 10	100	87	53
Chlordane 10	97	87	50
Lindane 1	88	90	47
BHC (gamma isomer) 1	90	83	10
Parathion 1	97	53	10
Untreated check	0	0	0

DDT was just as effective as chlordane, BHC (2 per cent gamma isomer), or parathion when weevils were introduced into the cages at once (table 1). The other dusts were less effective.

DDT, BHC (2 per cent gamma isomer), and lindane did not decrease in toxicity within 5 days after application, but became less toxic in 10 days. The other materials became less toxic in 5 days. (Table 2.)

Although the plants are dusted much more thoroughly in cage tests than in the field, these experiments indicate the necessity of careful and frequent applications when weevil infestations are heavy.

FIELD TESTS IN 1947.—DDT was also compared with other new insecticides in the field in 1947. A pepper field known to be infested was arranged in a randomized-block design with six replicates. Each plot was 10 rows wide by 50 feet long. Insecticides were applied with hand dusters at the rate of 25 pounds per acre at weekly intervals from July 29 to September 9. The degree of infestation was determined by counting the infested and uninfested pods on 5 plants per plot 1, 3, and 5 weeks after the first application. Yield was determined by weighing all the pods from each plot at harvest time. The results are shown in table 3.

In pepper weevil control significant differences are often difficult to demonstrate because of uneven distribution of the infestation in experimental fields. Untreated plots nearest the source of weevil spread in this field had two to three times as many infested pods per plant as similar plots farther away. Treated plots were unevenly infested owing to their position in relation to untreated plots and

Table 3.—Number of infested pods per plant and yield of peppers following six applications of various dusts for pepper weevil control. 1947.

Dust (Per Cent of Active Ingredient)	Number of Infested Pods After—			Per Cent Control	Yield per Acre (Pounds)
	1 week	3 weeks	5 weeks		
DDT 10	1.3	3.2	2.8	76	9346
5	1.0	1.6	1.4	87	7700
BHC (gamma isomer) 2	1.7	2.4	1.3	89	9796
Toxaphene 10	2.0	3.1	3.2	73	8225
Cryolite 70	2.2	3.3	3.5	70	7779
Chlordane 10	2.6	4.5	4.4	62	9275
Untreated	2.2	5.3	11.7	0	6725
L.S.D. at 5% level	n.s.	3.1	3.3	—	n.s.

to field edges. Nevertheless, DDT was as effective as the other insecticides tested. All of them reduced pepper weevil abundance and increased the yield 15 to 45 per cent over the untreated checks.

This experiment illustrates the difficulty of pepper weevil control when there is a continuous source of reinfestation. The same conditions prevail if intervals between applications are too long or if dusting is not carefully done.

FIELD TESTS IN 1953.[1]—Persistent rumors of pepper weevil resistance to DDT in California during 1952 led to an experiment in 1953 to investigate this problem. When the experiment was started, 75 per cent of the early pods were infested in the experimental area, located in San Diego County. Seven insecticide dusts were compared with an untreated check, in a randomized-block design with 5 replicates. Three applications at 30 pounds per acre were made at 10-day intervals, on July 17, 27, and August 6. Eighteen days after the third application all the pods on 5 plants per plot were examined for egg punctures. At this time considerable reinfestation had occurred because of weevil spread from untreated plots. Two more applications were made at 45 to 50 pounds per acre an August 25 and September 1. One week after the last application 100 small pods from the tops of the plants in each plot were examined for egg punctures. This method is the best for comparing insecticide effectiveness when the weevil population is unusually high. The results are shown in table 4.

Table 4.—Per cent of pods punctured by the pepper weevil on August 24, 18 days after the third application, and on September 8, 7 days after the fifth application of various dusts. 1953.

DUSTS (PER CENT OF ACTIVE INGREDIENT)	PER CENT OF PUNCTURED PODS		PER CENT CONTROL (SEPT. 8)
	On Aug. 24	On Sept. 8	
DDT 5	56	34	64
Aldrin 2.5	45	35	63
Heptachlor 3	56	47	50
TDE 5	66	48	49
Malathion 5	61	49	48
Parathion 2	62	71	24
Q-137 5	63	72	24
Untreated check	79	94	—
L.S.D. (at 5% level)	[1]	5.4	5.7

[1] Not significant according to the *F* test.

None of the dusts was sufficiently effective after the third application to show a significant difference from the untreated check, but 1 week after the fifth application distinct differences between materials were apparent.

The 5 per cent DDT was just as effective as 2.5 per cent aldrin, and more effective than any of the other insecticides, but malathion, TDE, and heptachlor were more effective than parathion or Q-137.

These experiments indicate not only that DDT is at least as effective as any of the other insecticides tried, but also that in a heavily infested field a 10 per cent DDT dust should be used, and frequent applications are required.

[1] This work was done in cooperation with L. D. Anderson California Agricultural Experiment Station, at Riverside.

LITERATURE CITED

Campbell, Roy E. 1924. Injuries to pepper in California by *Anthonomus eugenii* Cano. JOUR. ECON. ENT. 17: 645–7.

Campbell, Roy E. 1944. Tests of new insecticides against the pepper weevil at Alhambra, Calif. U.S.D.A. Bur. Ent. & Plant. Quar. **E-627.**

Elmore, J. C. 1933. Some tests with fluorine compounds against the pepper weevil, *Anthonomus eugenii* Cano. JOUR. ECON. ENT. **26:** 1095–1105.

Elmore, J. C., A. C. Davis, and Roy E. Campbell. 1934. The Pepper Weevil. U. S. Dept. Agr. Tech. Bul. **447.**

SCIENTIFIC NOTES

First Report of the Poultry Bug from a Golden Eagle's Nest, with New Locality Records

ROBERT D. LEE, *School of Tropical and Preventive Medicine, Loma Linda, California*

Haematosiphon inodorus (Dugès) has been reported from the nests of birds other than poultry; the birds are the California condor, great horned owl (Usinger 1947), and the barn owl (Lee 1954). Recently Dr. R. W. Strandtmann, Texas Technological College, kindly sent the author six specimens of *H. inodorus* which he and Mr. Robert Mitchell had taken from the nest of a golden eagle. The collection was made April 7, 1954, on the U Lazy S Ranch, about 10 miles south of Post, Garza County, Texas. Furthermore, Dr. Strandtmann states (*in litt.*), "Last year we found what I am certain is the same species of bug in an eagle's nest in Briscoe County near Silverton, Texas. We have also found it in old nests appropriated by great horned owls in Lubbock County, Texas." This is the first time *Haematosiphon* has been reported from the golden eagle.

To date the reported records of this ectoparasite from native birds indicate that it is associated with predaceous birds rather than with passerine birds. Related genera within the subfamily Haematosiphoninae (*Hesperocimex*, *Cimexopsis* and *Synxenoderus*) are found on swifts and martins.

The above locality records are the first specific records for the state of Texas. Townsend (1893) reported a rather general record for *Haematosiphon inodorus* as being from "western Texas." Dr. R. I. Sailer has generously granted permission for the inclusion in this paper of a number of previously unreported locality records, three of which are new county records for Texas. The data sent by Dr. Sailer were taken from specimens in the collection of the United States National Museum. They are as follows: Marfa, Presidio County, Texas, collected by F. C. Bishopp, VI-21-09, in a hen house, five specimens; Sabinal, Uvalde County, Texas, collected by F. C. Pratt, VI-1910, two specimens; Alpine, Brewster County, Texas, collected by F. C. Bishopp, X-26-10, one specimen; Deming, Luna County, New Mexico, collected by F. C. Pratt, V-17-09, one specimen; Silver City, Grant County, New Mexico, collected by W. B. McFarland, VII-15-16, in a dwelling, two specimens; Albuquerque, Bernalillo County, New Mexico, collected by J. Menifield, IX-3-28, ex. carpenter shop, nine specimens; Red Mountain, Atolia District, San Bernardino County, California, collected by Mrs. John Van N. Dorr, II-1940, swarms in old mine shaft, eight specimens.

Previously published county records for the state of New Mexico include Dona Ana County (Townsend 1893), Valencia County and Bernalillo County (Lee 1954). *Haematosiphon* has been reported by Usinger (1947) from the following California counties: Kern, Ventura, and Riverside.

Dr. Floyd G. Werner, University of Arizona, very kindly sent the author three specimens of *H. inodorus* taken August 10, 1928, in Lupton, Apache County, Arizona, collector unknown. Other counties in Arizona from which this species has been reported are Navajo County and Greenlee County (Lee 1954). The only other place known to the author where *H. inodorus* has been taken in the United States and not mentioned above is from Woods County, Oklahoma (Usinger 1947).

LITERATURE CITED

Lee, Robert D. 1954. New locality records and a new host record for *Haematosiphon inodorus* (Hemiptera: Cimicidae). Pan-Pac. Ent. In press.

Townsend, C. H. T. 1893. Note on the coruco, a Hemipterous insect which infests poultry in southern New Mexico. Proc. Ent. Soc. Wash. **3**: 40–1.

Usinger, R. L. 1947. Native hosts of the Mexican chicken bug, *Haematosiphon inodora* (Dugès). Pan-Pac. Ent. **23**(3): 140.

Use of Wettable Powder or Emulsion Formulations Compared with Mineral Seal Oil on Calves[1]

W. G. HOEKSTRA, R. J. DICKE, and P. H. PHILLIPS[2]

In the use of an insecticide on cattle it is necessary to consider not only its toxicity to insects, but also its effects on the animal to which it is applied. In a previous publication the production of a hyperkeratosis in calves with a topically applied oil-based insecticide carrier was reported (Hoekstra *et al.*, 1954). Although the condition produced in the calves was not the classical syndrome produced by the ingestion of highly chlorinated naphthalenes or feeds contaminated with such materials, it caused a thickened skin or a hyperkeratosis. A number of insect toxicants (lindane, methoxychlor, and thiocyanates) added to the oil did not enhance the toxicity of the oil itself. Other investigators have also reported the harmful effects of certain petroleum oils commonly used in cattle sprays (Atkeson *et al.* 1944, Regan & Freeborn 1936, Wilson *et al.* 1933).

It seemed desirable to investigate the effects of some commonly used insecticides when applied as wettable powders or emulsions on calves and to compare the effects with those produced by mineral seal oil.

PROCEDURE.—Twelve healthy Holstein-Friesian dairy calves weighing approximately 200–300 pounds were divided into six lots of two animals each. After a 3-week stabilization period they were treated as follows (the preparations were applied three times a week for 12 weeks):

Lot 1—Untreated (controls).
Lot 2—Sprayed with mineral seal oil[3] only.
Lot 3—Sprayed with a 0.5% water suspension of methoxychlor.[4]

[1] This investigation was supported (in part) by a research grant from the Standard Oil Company, Whiting, Indiana.

[2] From the Departments of Biochemistry and Entomology, University of Wisconsin, Madison. Published with the approval of the director of the Wisconsin Agricultural Experiment Station.

[3] As specified in a previous publication (Hoekstra *et al.* 1954).

[4] "Marlate 50," E. I. DuPont de Nemours & Company, Wilmington, Delaware.

Table 1.—Tabulation of the amounts of the various insecticide preparations used in the corresponding lots during the 12-week experimental period.

	LOT NUMBER[1]					
	1	2	3	4	5	6
No. times sprayed	—	35	35	35	29[2]	35
Total liters applied per calf	—	2.28	42.7	44.5	37.3	3.5
Average liters per calf per application (applied 3 times/week)	—	0.065	1.22	1.27	1.29	0.10

[1] See text for treatments of lots.
[2] A supply of this preparation was unavailable for 2 of the 12 weeks.

Lot 4—Sprayed with a 0.05% water suspension of lindane.[5]

Lot 5—Sprayed with a 5% water suspension of a sulfoxide pyrethrin wettable powder composed of 2% pyrethrin and 20% sulfoxide.[6]

Lot 6—Sprayed with a 1:9 water emulsion of a commercial pyrethrin-sulfoxide spray concentrate.[7]

The preparations used represent concentrations of the various insecticides recommended in practice. The oil and the emulsion were applied with hand sprayers and the suspensions with 3-gallon compressed air sprayers. The amount applied to each lot was measured by difference in a graduated cylinder. The suspensions and emulsions were prepared on each day of treatment. Table 1 shows the amounts of the preparations used over the 12-week experimental period. The calves were bled at 1- or 2-week intervals for blood plasma vitamin A analyses, since a sharp plasma vitamin A drop occurs in chlorinated naphthalene induced bovine hyperkeratosis. Previous work had indicated a measurable, but not critical, decrease in this value upon topical application of mineral seal oil. The calves were examined daily for evidence of hyperkeratosis or any other abnormalities. The experiment was conducted during March to July of 1953. No comparative evaluations of fly control were made for the various preparations used.

RESULTS.—Throughout the experiment the calves in lots 1, 3, 4, 5, and 6 were comparable. The wettable powders or the emulsion in the amounts used had no detectable effect on appetite, growth or general condition of the calves. No skin changes were observed in calves treated with these preparations. Blood plasma vitamin A concentrations of these animals did not digress significantly from those of the control calves.

The results with the mineral seal oil (lot 2) substantiate those previously reported (Hoekstra *et al.* 1954). A definite hyperkeratosis developed along the neck and shoulders, but appetite and growth were not greatly retarded. The slight transitory depression in plasma vitamin A occurred upon application of the oil, but again it appeared not to be critical.

It was evident from these results that the calves withstood heavy application of the insecticides tested in this manner. The amounts of the preparations applied were purposely used in considerable excess of normal practice. The applications used completely wet the animal to a point of considerable "run off" of the suspension. These treatments were made three times a week for 12 weeks, a time considered sufficient for any practical harmful effect to appear and also a reasonable period for fly control practices in the northern section of the United States. It should be stressed that the concentrations of the insecticides employed in this work were those recommended in practice.

In this study only a limited number of the more commonly used insecticides were tested. It should be mentioned that the highly chlorinated naphthalenes are the principal known causative agents of bovine hyperkeratosis. Pentachlorophenol, a compound rather closely related to chlorinated naphthalenes, although toxic, does not produce hyperkeratosis. The factors involved in the production of a hyperkeratosis by certain mineral oils are not understood at the present time, but may represent either a chemical or a physical phenomenon or a combination of both of these.

In view of the results of this experiment and those previously reported (Hoekstra *et al.* 1954), it is temporarily necessary to recommend wettable powder or emulsion formulations for direct application to calves until such time as the petroleum oils-hyperkeratosis problem is resolved.

LITERATURE CITED

Atkeson, F. W., A. R. Borgmann, R. C. Smith, and A. O. Shaw. 1944. Relative effects of several base oils used in livestock sprays on the skin of cattle. JOUR. ECON. ENT. **37:** 419–28.

Hoekstra, W. G., R. J. Dicke, and P. H. Phillips. 1954. Production of hyperkeratosis in calves with a topically applied oil-based insecticide carrier. Amer. Jour. Vet. Res. **15:** 47–50.

Regan, W. M., and S. B. Freeborn. 1936. The effect of flies and fly sprays on certain physiological processes of the dairy cow. Jour. Dairy Sci. **19:** 11–28.

Wilson, J. L., A. M. Pearson, and C. Y. Cannon. 1933. The effects of some fly sprays on the hides and on the body temperature of dairy cows. Jour Dairy Sci. **16:** 427–33.

[5] "Isotox Dairy Spray," California Spray-Chemical Corporation, Richmond, California.
[6] "Sulfoxide-Pyrexel Wettable Powder," S. B. Penick and Company, Chicago, Illinois.
[7] "Pyrexel Mill Spray Concentrate," S. B. Penick and Company, Chicago, Illinois.

Cuterebra lepivora Reared from *Sylvilagus audubonii sanctidiegi* in San Bernardino County, California

RAYMOND E. RYCKMAN and CHESTER C. LINDT,
School of Tropical and Preventive Medicine, Loma Linda, California

A female rabbit, *Sylvilagus audubonii sanctidiegi* Miller, was live trapped near Loma Linda, San Bernardino County, California, on May 27, 1953. This rabbit was parasitized by six Cuterebrid larvae at the time of capture; mature larvae were collected and reared from the host by the method described by Ryckman (1953). Larvae left the host and pupated on May 31, June 9, 16, and 25; three adults, two males and one female, emerged on September 18, 19, and 20, 1953. The rabbit, fly pupae, and adult *Cuterebra* were all reared at laboratory room temperature throughout the experiment.

The male and female which emerged on September 19 and 20 were confined together in a sleeve cage 30 inches long, 17 inches deep, and 19 inches in height; after a 24-hour period both flies were confined in a pint jar covered with nylon. Blotter paper placed vertically in the jar served as a substratum for the flies to walk on. Maltine diluted with water was supplied for food; neither of the flies were observed to take nourishment.

The female began laying eggs at 11:00 A.M., September 23, and during the following 24 hours laid 148 eggs. At the most active egg laying period 11 eggs were laid in 60 seconds. During a 72-hour period a total of 242 eggs were laid by this female. The eggs were deposited singly on the nylon jar cover, blotter paper, and inner surface of the glass jar. When oviposition first began the eggs were laid rapidly, and frequently were end to end in rows as shown in figure 1. A typical oviposition pattern is as follows: the female would lay an egg, take one or two steps forward, and then lay a second egg and continue this activity until long rows of eggs appeared on the nylon and inner surface of the glass jar in which the female was confined. Egg shape and texture of the chorion are shown in figure 2. When laid, the eggs are covered with a clear mucilaginous fluid which upon hardening cements the eggs firmly to the substrata.

Eggs laid 11:00 A.M., September 23, began hatching at 4:00 P.M., September 28. An experiment was conducted to determine how long the larvae were capable of living before entering a rabbit host. Larvae which hatched from eggs on September 28 were confined in a clean, stoppered shell vial; they began dying on September 30 and were all dead on October 4. Under laboratory conditions the maximum life of recently hatched larvae was not in excess of 6 days.

Larvae of *Cuterebra lepivora* Coq. are capable of standing upright by an attachment organ on the posterior end of their bodies. Larvae placed on the arm of the author (Ryckman) and studied under a dissecting microscope seemed to seek elevated points and were frequently observed to attach, by the posterior organ, to hair on the arm and stand upright, figure 3. The larvae were also placed in a drop of water on the author's arm and studied under a dissecting microscope; under moist conditions the larvae crawled about aided by oral hooks and a forward bunching of the cuticle rings of the abdominal segments, after which the internal body moved forward and flowed into the bunched integumentary segments. The larvae made no attempt to penetrate dry or moist skin on the author's arm. A first instar larva is shown in figure 3.

An attempt was made to infect domestic rabbits with first instar larvae of *Cuterebra lepivora* by ingestion and application of the larvae to the skin. Twelve larvae were released at the base of the hair on the back of an adult female laboratory rabbit; after 7 months there was no indication of parasitism. Twelve larvae were placed on a small piece of lettuce and fed to a second adult laboratory rabbit. This rabbit died approximately 1 week after exposure to the parasites. On autopsy, two larvae were recovered

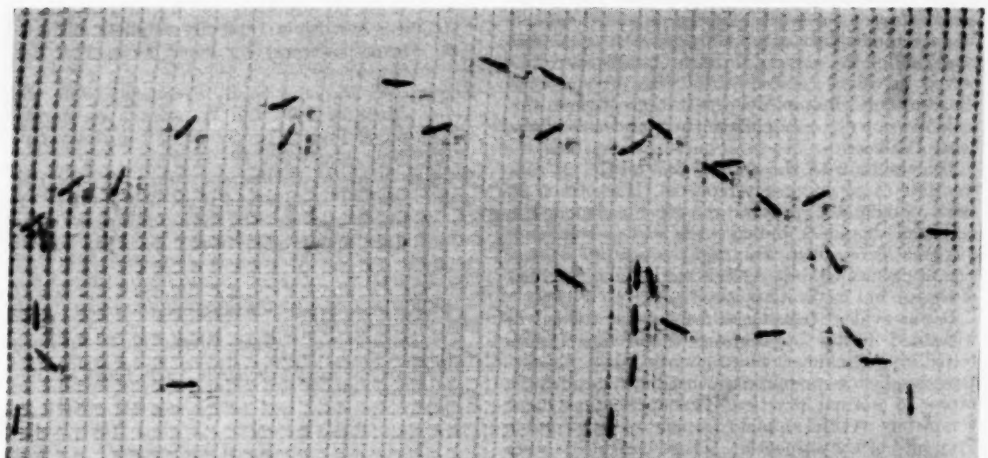


FIG. 1.—Eggs of *Cuterebra lepivora* Coq. laid on nylon cloth. The anterior or operculum end of the egg in this figure is shown as a dark plate at the end of the egg.

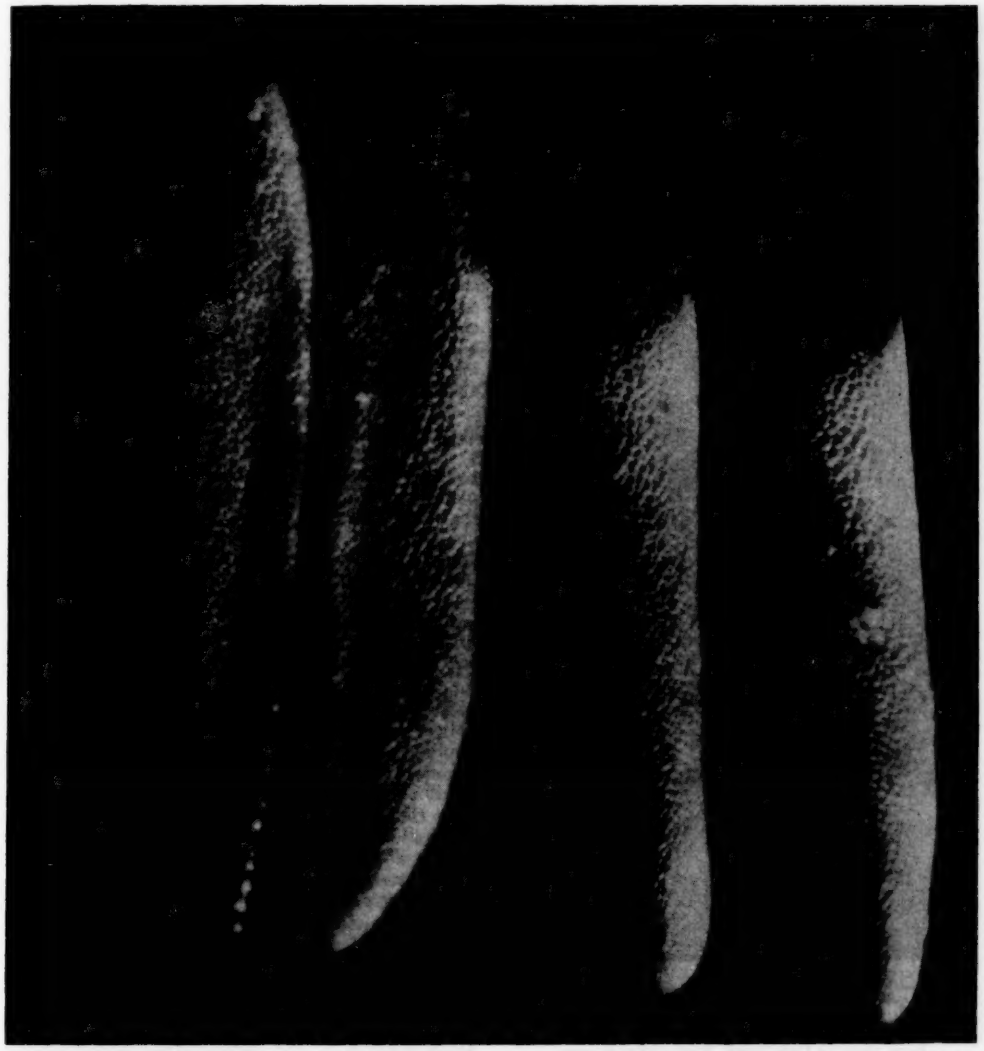


FIG. 2.—*Cuterebra lepivora* eggs dorsal and lateral view. The operculum is located anteriorly and dorsal; the egg on the right has the operculum removed. Note the pitted texture of the chorion.

from this rabbit; one larva was in subdermal layers of the skin on the ventral throat region; the second larva was recovered in the fascia between the skin and muscles on the left side of the neck.

Twenty larvae were placed in water, picked up with a pipette and pipetted into the open mouth of an adult domestic rabbit. This rabbit also died approximately 1 week after inoculation. No larvae were recovered from this rabbit on autopsy, however, a hemorrhage was present near the trachea in muscle tissue of the neck.

Beamer *et al.* (1943) reported that *Cuterebra beameri* Hall laid eggs in or near the entrance to wood-rat nests; the authors did not suggest how *Cuterebra beameri* parasitized *Neotoma floridana osagensis* Blair. In the opinion of the writers, Cuterebrids parasitizing *Neotoma* enter the host by ingestion. On occasion it became necessary to remove first instar larvae of *Cuterebra lepivora* from vials or other receptacles in the laboratory. These larvae were usually standing erect, and when touched by a camel's hair brush seemed to become entangled in the hairs and were very difficult to dislodge. It would seem that wood-rats brushing against larvae in their nests would also readily pick up the parasite larvae on their fur. *Neotoma* frequently lick their paws and fur and in this way could ingest the larvae of *Cuterebra*. *Cuterebra lepivora* have been shown to lay 148 eggs in 24 hours. When a species produces many eggs and yet maintains itself at a low level in nature it is an indication that a relatively small per cent reach a susceptible host.

A study of the behavior of first instar larvae and results of experimental infections in domestic rabbits would seem to indicate that in nature rabbits become parasitized by ingestion of the larvae on vegetation. The authors have seen Cuterebridae flying about low shrubbery in canyons of Baja Cali-

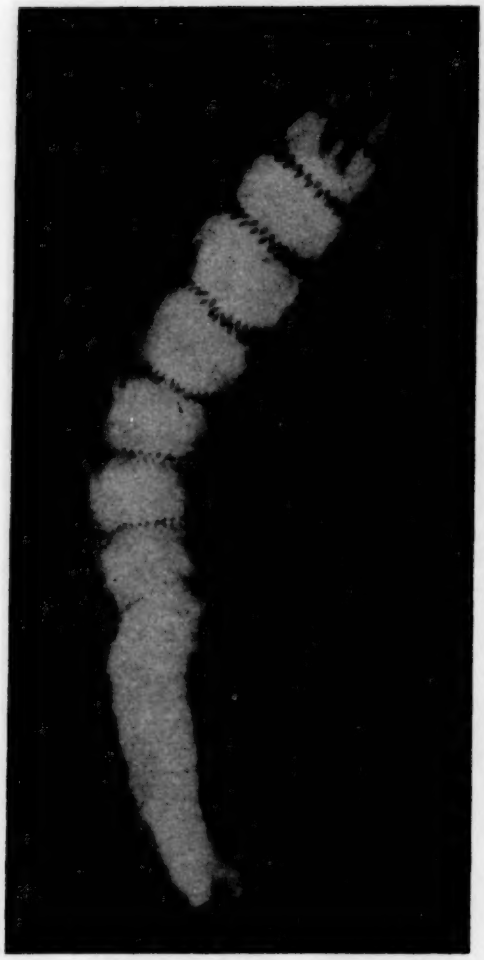


FIG. 3.—First instar larva of *Cuterebra lepivora*. The organ of attachment, which permits the larva to stand erect, is located on the caudal region and is here seen as two thick, fleshy structures.

fornia in Mexico. Adults of *Cuterebra lepivora* were identified by Curtis W. Sabrosky of the Entomology Research Branch of the U. S. Department of Agriculture.

LITERATURE CITED

Beamer, R. H., L. R. Penner, and C. W. Hibbard. 1943. Some notes on the biology of the pack rat Cuterebrid (*Cuterebrid* [sic.] *beameri* Hall) in Kansas. Jour. Kansas Ent. Soc. **16**(2): 47–50, incl. 1 pl.

Ryckman, Raymond E. 1953. *Cuterebra latifrons* reared from *Neotoma fuscipes macrotis* (Diptera: Cuterebridae) Pan-Pac. Ent. **29**(3): 155–6.

Three New Phosphate Insecticides for the Systemic Control of Cotton Insects

E. E. IVY, A. L. SCALES, and L. J. GORZYCKI,
Entomology Research Branch, Agr. Res. Serv., U.S.D.A.[1]

One goal of the research program at the Cotton Insect Basic Research Laboratory at College Station, Texas, operated jointly by the United States Department of Agriculture and the Texas Agricultural Experiment Station, has been the development of systemic insecticides that are effective against chewing insects. We have particularly tried to find compounds that are effective against the boll weevil, the bollworm, the cotton leafworm, and the pink bollworm. In our screening program we have found many compounds that are effective systemically against aphids and spider mites. Most of the research on systemic compounds in this country and abroad has been concentrated on these pests.

With few exceptions the species that may be controlled with systemic compounds feed by sucking plant sap. However, we do have a few compounds that are systemically active against certain chewing insects. Results of tests with systemic compounds against the pink bollworm were reported by Ivy (1953a). In the present paper some new compounds that appear to show systemic activity against the boll weevil as well as several other cotton insects will be described.

We have concentrated largely on seed treatments for the systemic application. The compounds that are most effective against chewing insects such as the boll weevil do not appear to be translocated when applied as sprays in the conventional manner, but some of them are translocated in sufficient quantity to kill many chewing insects when applied to the soil or to the seed (Ivy 1953b). Much lower dosages are required for seed treatments than for soil application (Ivy *et al.* 1950). An activated-carbon carrier is used for the seed coating (Ivy 1952). In this way much higher dosages of the systemic compounds are tolerated by the seed and seedling plants than if a liquid dip were used, and the treatments are more persistent.

Some of the compounds that kill boll weevils placed on seedling plants grown from seed receiving systemic treatments are parathion, methyl parathion, para-oxon, and several other closely related compounds. Unfortunately, however, each of these compounds inhibits germination, and injures seedling plants when applied at dosage levels required for effective control. Demeton and a number of related thiophosphates are less effective against the boll weevil and are also phytotoxic when used for seed treatment.

Three compounds recently developed by an American manufacturer appear to possess a high degree of activity against chewing insects and at the same time have little or no effect upon seed germination or on the development of the seedling plant from treated seed. They are TM 12008 (0,0-diethyl S-isopropyl mercaptomethyl dithiophosphate), TM 12009 (0,0-diethyl S-propyl mercaptomethyl dithiophosphate), and TM 12013 (0,0-diisopropyl S-isopropyl mercaptomethyl dithiophosphate).

The procedures used in these tests have been described by Ivy (1952). From 30 to 60 adults of the boll weevil, *Anthonomus grandis* Boh., or newly

[1] In cooperation with the Texas Agricultural Experiment Station.

Table 1.—Per cent mortality in 5 days of boll weevils and cotton leafworms placed at various intervals on plants grown from seed treated with three mercaptomethyl dithiophosphates.

Compound	Seedlings Pulled from Soil After/Week	Laboratory Tests: Plants Growing in Cans for— 2 Weeks	3 Weeks	4 Weeks	Field-Cage Tests After— 5 Weeks	6 Weeks
		Boll Weevils				
TM 12008	100	100	72	63	11	0
TM 12009	100	83	31	0	0	0
TM 12013	83	12	0	0	0	0
Check (toxaphene spray 2 pounds per acre)	84	62	59	60	53	42
		Cotton Leafworms				
TM 12008	100	100	100	97	74	59
TM 12009	100	100	93	26	0	0
TM 12013	100	88	4	0	0	0

hatched larvae of the cotton leafworm, *Alabama argillacea* (Hbn.), were used in each test. Included also were from 200 to 300 cotton aphids, *Aphis gossypii* Glov., or desert spider mites, *Tetranychus desertorum* Banks; from 50 to 75 adults of the cotton fleahopper, *Psallus seriatus* (Reut.); 10 newly hatched larvae of the salt-marsh caterpillar, *Estigmene acrea* (Drury), or of the bollworm, *Heliothis armigera* (Hbn.); or 10 flower thrips, *Frankliniella tritici* (Fitch). Moths of the cotton leaf perforator, *Bucculatrix thurberiella* Busck, were permitted to oviposit on the treated plants, and approximately 300 eggs were tested for each compound.

The compounds were applied to the seed at the rate of 4 pounds per 100 pounds of seed. Results of tests against the boll weevil and the cotton leafworm are presented in table 1. Each compound was highly effective on seedlings infested 1 week after treatment, but TM 12008 retained its toxicity for the longest time.

In tests with several other cotton pests conducted 3 weeks after treatment each of the compounds killed all cotton aphids, desert spider mites, and cotton fleahoppers placed on the plants. TM 12008 and TM 12009 killed all larvae of newly hatched cotton leaf perforators and of salt-marsh caterpillars, but TM 12013 was only slightly effective. TM 12008 was effective and TM 12009 less effective against flower thrips. TM 12013 was not tested against this species. None of the materials were effective against the bollworm.

Literature Cited

Ivy, E. E. 1952. Testing systemic insecticides. Agr. Chem. 7(11): 44–5, 121, 123.

Ivy, E. E. 1953a. Systemic insecticides. Cotton Gin and Oil Mill Press 54(6): 85–6.

Ivy, E. E. 1953b. Chemical characteristics of phosphorus compounds to kill aphids and spider mites by systemic action. Agr. Chem. 8(4): 47–50, 137, 139.

Ivy, E. E., Wm. Iglinsky, Jr., and C. F. Rainwater. 1950. Translocation of octamethyl pyrophosphoramide by the cotton plant and toxicity of treated plants to cotton insects and a spider mite. Jour. Econ. Ent. 43(5): 620–6.

A New Pest of Cotton in Texas[1]

D. F. Martin and W. J. Mistric, Jr., *Texas Agricultural Experiment Station, College Station*

A brown cotton leafworm, *Acontia dacia* Druce, caused considerable "ragging" of cotton in certain fields of South Central, Eastern and Upper Coastal areas of Texas especially in Brazos, Burleson, Robertson, Wharton and Matagorda Counties. Noticeable damage to the foliage began to appear during the first week in July, 1954. By mid-July severe damage by the worms extended over several thousand acres of cotton. Collections of this insect were made in 1953 by C. R. Parencia, Entomology Research Branch, U. S. Department of Agriculture, on July 6, 7, and 8 in Austin, Robertson and Wharton Counties although no damage was reported at that time.

Nature of Damage.—The damage appears first as small "buck shot" holes in the cotton leaves, and are enlarged as the larvae continue to feed. Plants may be completely defoliated if heavy infestations occur. The larvae have been reported attacking squares and bolls.

Description of Egg, Larva and Adult.—The egg, about the size of the cotton bollworm egg, is bluish-green when newly laid but becomes mottled with reddish blotches several hours after deposition. The egg is more pointed at the micropyle than the bollworm egg being slightly sub-cone shaped. The height of the egg is somewhat greater than the width at the base.

The larva, which crawls with a looping motion, has three pairs of prolegs (two abdominal and the anal) and is reddish-brown in color. When full grown it measures approximately $1\frac{1}{4}$ inches in length. One black spot is located on each side of the body just behind the third pair of thoracic legs and an irregular pale yellowish-white line extends posteriorly almost to the hind end of the larva along the sides of the body from each spot.

The moth is about $\frac{1}{2}$ inch long with a wing spread

[1] Technical Contribution No. 2019, Texas Agricultural Experiment Station in Cooperation with Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

Table 1.—Results of laboratory tests for the control of *Acontia dacia* with insecticides. College Station, Texas. 1954.

Treatment	Dosage[1] Spray	Dosage[1] Dust	Per Cent Control[2]
Toxaphene	2		62
	3		53
Parathion	0.25		100
	0.125		100
Endrin	0.25		81
	0.33		90
DDT	1		18
	1.5		31
Malathion	0.25		100
	0.5		100
BHC (g.i.)	0.30		13
	0.40		40
Cryolite		10	46
		15	47
Calcium arsenate		10	23
		15	41

[1] Pounds active ingredients per acre.
[2] Abbotts formula used to calculate percentage control.

of approximately 1 inch. The upper surface of the wings of the female is yellowish-gray; the fore wings are dark brownish on the apical two-thirds or more. The upper surface of the wings of the male is pale gray with the tips of the fore wings blackish.

CONTROL.—Population build-ups and damage occurred in fields being treated regularly with most of the chlorinated hydrocarbon insecticides recommended for control of various insects attacking cotton.

Results of preliminary laboratory tests are shown in table 1. Effective control was obtained with parathion, malathion and endrin. Toxaphene, DDT, cryolite, BHC and calcium arsenate were ineffective at the dosages used.

Results of a field test are shown in table 2. Materials were applied by airplane. Initial infestation counts were made immediately before the insecticides were applied. Subsequent records were taken 24 hours after treatment.

SUMMARY.—A brown cotton leafworm, *Acontia dacia* Druce, appeared as a new pest of cotton in the South Central, Eastern and Upper Coastal areas of Texas producing economic damage to several thousand acres of cotton during July, 1954. This insect was collected in cotton fields during 1953; however, no economic damage was reported.

Preliminary laboratory and field tests indicate that 0.25 pound of parathion or 0.33 pound of endrin per acre is effective for control of this pest.

Table 2.—Results of a field test for control of *Acontia dacia* with insecticides. College Station, Texas. 1954.

Material	Dosage[1] Spray	Dosage[1] Dust	Per Cent Reduction
Parathion	0.25		100
	0.50		100
Endrin	0.33		97
BHC (g.i.)	0.40		77
5-10-40[2]		10	0

[1] Pounds active ingredients per acre.
[2] Five per cent gamma isomer BHC—10 per cent DDT—40 percent sulfur.

The Red-Headed Ash Borer in Idaho

WILLIAM F. BARR and H. C. MANIS,
University of Idaho, Moscow

The red-headed ash borer, *Neoclytus acuminatus* (F.), is a well-known pest of a wide variety of broad leaf trees in the eastern United States. In the western part of its range in Colorado the subspecies, *hesperus* Linsley is associated with oak. No published records of the occurrence of *N. acuminatus* west of the continental divide have been noted.

Since 1948 many specimens of the red-headed ash borer, which most closely resemble the eastern form of the species, have been seen from several localities in southwestern Idaho (Boise, Nampa, Parma, and Payette). This species apparently is well established in this area and has become a rather serious pest to farm woodlot and windbreak plantings of black locust. Young black locust trees in an apparently healthy condition have been found to be heavily infested with larvae of the borer on several occasions. Generally, however, older or weakened trees and freshly cut or seasoning wood are most heavily attacked. In addition to black locust, the red-headed ash borer has been found in the wood of apple and has been reported infesting soft maple and trumpet creeper, (*Campsis* sp.), in Idaho.

Control of the Strawberry Weevil in Blackberries

W. G. EDEN, *A.P.I. Agricultural Experiment Station, Auburn, Ala.*

The strawberry weevil, *Anthonomus signatus* Say, is an important pest of cultivated blackberries in the fruit- and berry-growing area near Clanton, Alabama. Thomas (1945) failed to obtain satisfactory control of the strawberry weevil on strawberries with arsenical and fluorine compounds. Fulton (1949) recommended 5 per cent DDT dust for strawberry weevil control on strawberries and dewberries in North Carolina. In controlling weevils on strawberries, Christ & Driggers (1949) reported promising results from dusts of 5 per cent chlordane and 1 per cent gamma isomer of BHC.

An experiment was conducted for 3 years on control of the strawberry weevil on blackberries at the Chilton Area Horticulture Substation at Clanton, Alabama.

PROCEDURE.—The treatments were wettable powder sprays of DDT, chlordane, and toxaphene. Two pounds of fermate were used per 100 gallons of spray for disease control on all plots including the checks. The treatments were replicated four times in randomized blocks. Plot size was a 100-foot section of berry rows. Rows were 10 feet wide.

The sprays were applied with a three-nozzle hand boom connected by a 50-foot hose to a power sprayer. The sprays were applied at 300 pounds pressure in sufficient quantity to wet the foliage. Three sprays were applied each year to the vines. Spraying was started when the vines began to produce buds freely. Interval between sprays was from 1 to 2 weeks, depending on the rate of bud production. The average interval between the last spray and the first picking of ripe berries was from 3 to 4 weeks. Control of the weevil was measured by the percentage of buds infested and the yield of marketable berries.

RESULTS.—The weevil infestation in the blackberry buds after the first and second sprayings in 1954 is presented in table 1. The average infestation

Table 1.—Infestation of blackberry buds and yield of fruit following sprays[1] for control of the strawberry weevil. Clanton, Alabama, 1952–53–54.

TREATMENT[2]	PERCENTAGE OF BUDS INFESTED, 1954[3]		YIELD IN POUNDS PER ACRE BY YEARS[3]			
	April 12	April 19	1952	1953	1954	Mean
None	9.3	13.5	8,149	7,931	11,967	9,349
DDT, 1 lb.	4.0	.8	9,851	9,341	13,589	10,927
Chlordane, 1 lb.	2.8	2.8	9,435	8,040	12,828	10,101
Toxaphene, 2 lb.	2.5	.5	10,028	9,735	13,733	11,195
			L.S.D. at 5%			498

[1] Applied April 5, 12, and 19 in 1954.
[2] Indicated amounts were used per 100 gallons of water. All plots received sprays containing 2 pounds of fermate per 100 gallons.
[3] Mean of four replications.

in the check plots was 9.25 per cent 1 week after the first spraying of the treated plots and 13.5 per cent 1 week after the second spraying. The infestations were obviously reduced by the use of all three insecticides.

The yields of marketable berries by years are also presented in table 1. Toxaphene, DDT, and chlordane were all significantly effective in controlling the weevil, with consequent increases in berry yields. Toxaphene was the most effective insecticide, being significantly better than DDT. Chlordane was the east effective of the three.

SUMMARY.—An experiment was conducted for 3 years in Alabama on control of the strawberry weevil, *Anthonomus signatus* Say, on blackberries with wettable powder sprays of toxaphene, DDT, and chlordane. The use of all three insecticides resulted in significant increases in yields of marketable berries. Toxaphene was significantly better than DDT, and DDT was significantly better than chlordane.

LITERATURE CITED

Christ, E. G., and **B. F. Driggers.** 1949. Strawberry weevil control with new organic insecticides. JOUR. ECON. ENT. **42**(3): 559.

Fulton, B. B. 1949. The strawberry weevil. N. C. Agr. Expt. Sta. Ext. Cir. **336(C).**

Thomas, W. A. 1945. Experiments with insecticides to control the strawberry weevil in North Carolina and Maryland. JOUR. ECON. ENT. **38**(6): 678–82.

Grasses as Hosts of the Greenbug

R. G. DAHMS, R. V. CONNIN, and W. D. GUTHRIE,[1]
Entomology Research Branch, Agr. Res. Serv., U.S.D.A.[2]

The survival of the greenbug, *Toxoptera graminum* (Rond.), during the summer is dependent upon

[1] Formerly research assistant, Oklahoma Agricultural Experiment Station.
[2] In cooperation with the Oklahoma and Kansas Agricultural Experiment Stations.

Table 1.—Greenbug reproduction on seedling grasses growing in the greenhouse.[1]

SCIENTIFIC NAME[2]	COMMON NAME	GROWING SEASON	INCREASE IN NUMBER OF GREENBUGS PER PARENT IN 8 DAYS	
			Stillwater	Manhattan
**Aegilops cylindrica* Host.	Jointed goatgrass (Wa)[3]	May–June	76.3[4]	10–20
**Andropogon furcatus* Muhl.	Big blue-stem (P)	July–Sept.	23.5	10–20
**Andropogon ischaemum* L.	Yellow bluestem (P)	June–Sept.	.03	—
**Andropogon saccharoides* Swartz.	Silvery beard-grass (P)	June–Aug.	11.3	—
Bromus commutatus Schrad	Hairy brome (A)	Apr.–June	10.6	—
Bromus catharticus Vahl.	Rescue-grass (A)	Apr.–Aug.	12.8	—
Bromus secalinus L.	Cheat (A)	Apr.–Aug.	8.1	—
Bromus tectorum L.	Downy chess (A)	May–July	—	5–10
**Buchloe dactyloides* (Nutt.) Engelm.	Buffalo grass (P)	May–July	.04	—
**Cenchrus pauciflorus* Benth.	Sand bur (A)	July–Oct.	23.7	10–20
Cynodon dactylon (L.) Pers.	Bermuda grass (P)	Apr.–Oct.	9.0	—
**Digitaria sanguinalis* (L.) Scop.	Crabgrass (A)	June–Sept.	10.8	—
Echinochloa crus-galli (L.) Beauv.	Barnyard-grass (A)	June–Oct.	0	0–1
Elymus canadensis L.	Canada wild-rye (P)	July–Aug.	9.1	0
Elymus virginicus L.	Virginia wild rye (P)	June–Aug.	—	5–10
**Eragrostis curvula* (Schrad.)	Weeping love-grass (P)	Apr.–Oct.	5.3	—
Hordeum pusillum Nutt.	Little barley (A or Wa)	Apr.–June	10.2	—
**Panicum virgatum* L.	Switch-grass (P)	Aug.–Sept.	.5	1–2
Paspalum pubiflorum glabrum Vasev.	——— (P)	June–Oct.	0	—
**Phalaris caroliniana* (Walt.)	Canary-grass (A)	May–Aug.	6.3	—
**Sorghastrum nutans* (L.) Nash.	Indian-grass (P)	July–Sept.	.7	1–2
Sorghum halepensis (L.) Pers.	Johnson-grass (P)	Apr.–Oct.	10.0	5–10
Triodia flava (L.) Smyth.	Purple-top (P)	June–Oct.	0	—

[1] Information on nomenclature and habitat obtained from Grasses in Kansas, Rpt. Kans. State Bd. of Agr., 55: 220-A, (1936), by Frank C. Gates; and Grasses of Oklahoma, Oklahoma Agr. Tech. Bul. 3 (1938), by H. I. Featherly.
[2] Species indicated by asterisk (*) were not included in the list by Patch (1938).
[3] Habit designated in parenthesis as follows: A, annual; P, perennial; Wa, winter annual.
[4] Several adults present on these plants, indicating that some of this increase was due to adults that matured in less than 8 days.

volunteer grains and wild grasses. Therefore, it is important to know the grasses that may serve as host plants to this insect. Patch (1938) listed 62 food plants for the greenbug. However, she gave no information as to the ability of the greenbug to reproduce and maintain a population on them.

In tests of small grains for resistance to greenbugs and in studies on the transmission of small grain diseases by insects, information has been obtained on the relative importance of several grasses as host plants of this insect. The work was conducted in greenhouses at Stillwater, Oklahoma, and Manhattan, Kansas. Grass seeds were planted in 6-inch flower pots and allowed to grow for 24 to 28 days. Three plants were used in each pot, and each test was duplicated. This gave records on six plants of each variety. At Stillwater each plant was infested with four 6-day-old greenbugs and covered with a cellophane cage, and 8 days later the greenbugs on each plant were counted. At Manhattan the age of the aphids used to infest the plants was not known; therefore, the increase in 8 days was estimated rather than counted. The results of these tests are given in table 1.

Only two species tested, *Paspalum pubiflorum glabrum* and *Triodia flava*, failed to maintain a greenbug population. Greenbugs were unable to live on *Echinochloa crusgalli* at Stillwater, but did survive at Manhattan. On the other hand, greenbugs reproduced on *Elymus canadensis* at Stillwater, but not at Manhattan. *Aegilops cylindrica*, *Cenchrus pauciflorus*, and *Andropogon furcatus* were the three most favorable hosts at both places.

The ideal oversummering host for greenbugs should be a plant that has a growing season from April or May to September or October. Three grasses apparently fulfill this requirement—*Eragrostis curvula*, *Cynodon dactylon*, and *Sorghum halepensis*. The last two are especially plentiful in the Southern States. However, it would, of course, be possible for greenbugs to live for a while on an early season grass such as *Aegilops cylindrica* and migrate to a later grass such as *Digitaria sanguinalis*.

LITERATURE CITED

Patch, E. M. 1938. Food plant catalogue of the aphids of the world including the Phylloxeridae. Maine Agr. Expt. Sta. Bull. 293:35–431.

The Effectiveness and Limitations of Homemade Self-Treatment Rubbing Devices for Louse Control on Cattle

ROBERT A. HOFFMAN, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The successful control of horn flies, *Siphona irritans* (L.), on cattle by self-treatment rubbing devices has been reported by Rogoff & Moxon (1952) in South Dakota and by Lindquist & Hoffman (1954) in Oregon. During the winter of 1952–53 the author (Hoffman 1954) conducted preliminary tests to determine whether similar devices might be effective for the control of lice on cattle. In view of the promising results of those tests, further experiments with homemade rubbing devices were made during the past winter in an attempt to determine the limitations of the method and to establish the relative effectiveness of four common chlorinated hydrocarbon insecticides.

METHODS AND MATERIALS.—The rubbing devices were placed under various conditions—in paved lots as well as one 12 inches deep with mud, in both covered and uncovered situations, across corners of fences, and in open fields. The 2-pole swinging-type unit described by Rogoff & Moxon (1952) and a single center-pole, tightly strung type of our own design were used. The four strands of barbed wire were wrapped with burlap sacking, and the sacking was secured to the wire with twine and wire ties. Cattle were of both dairy and beef types.

Chlordane, DDT, methoxychlor, and toxaphene were used in the tests. Each material was applied to four units as a 5-per cent solution in No. 2 fuel oil at a rate of 200 ml. per running foot of sacking, 150 ml. being applied at the start of the test and 50 ml. at the time of the 3-week check. In two tests a 2.5-per cent solution of DDT was used.

Both the biting louse, *Bovicola bovis* (L.), and the sucking louse, *Linognathus vituli* (L.), were present on the animals, the biting louse being most common on Hereford and Jersey cattle and the sucking louse on those of Holstein breeding. Estimates of louse populations were obtained by counting the lice in ten 1-square-inch areas—one each on the poll, shoulders, lower neck, and dewlap, two along the back, one at the base of the tail, one on the hind quarters, and two in the lateral abdominal region. Counting was facilitated by use of a cardboard having a hole 1 inch square.

RESULTS.—Control obtained with the rubbing units, as shown in table 1, appeared to be dependent chiefly on the physical features of the feed lot or pasture. In situations that were brushy, had many trees, or were deep in mud, control was usually poor. The adverse effect of extreme mud conditions was especially well demonstrated in herds 13 and 14, even though the cattle were observed using the equipment extensively. On the other hand, herds 8 and 18, using units established on dry ground but otherwise similar to herds 13 and 14, provided control of 94 per cent or better within 3 weeks.

All four insecticides gave good control in at least one test under favorable conditions, but failed at the same time under adverse conditions. Although toxaphene gave excellent control the greatest number of times, it is evident that any one of these materials is satisfactory when used in a 5-per cent solution. Even a 2.5-per cent solution of DDT provided good control under selected conditions.

The cattle used both devices without hesitation. However, our tight-wired, single-pole unit was more easily abused and required repair service more frequently than the loosely suspended Rogoff type. Furthermore, the cattle were more likely to use units placed on open ground than those in close quarters across the corners of fences.

No preference was noted for units under cover of a feed shed to those in the open exposed to the weather. Control was obtained with units under both conditions. Leaching of the oil solution by rain was apparently slight, as no excessive oil spots were observed beneath the units.

When both species of lice were present on the same animals, the biting louse population decreased more readily than did that of the sucking louse. It is probable that activity and feeding habits account for this difference.

It is concluded that the self-application method described, using some of the chlorinated hydrocar-

Table 1.—Control of cattle lice with self-treatment rubbing devices.

Insecticide	Cattle: Herd No.	Cattle: Number	Cattle: Breed	Species of Lice	Location of—: Animals	Location of—: Unit	Number of Lice Before Exposure[1]	Per Cent Reduction After—: 1 Week	3 Weeks	6 Weeks	9 Weeks
DDT 5%	1	40	Holstein	*vituli*	Feed lot	Under cover	27	27	63	77	91
	3	50	Mixed	*vituli*, *bovis*	Feed lot	In open	25	16	60	—	94
	10	13	Holstein	*vituli*	Feed lot	In open	19	54	93	94	87
	11	11	Mixed	*vituli*, *bovis*	Feed pen	Under cover	23	35	86	96	98
DDT 2.5%	2	31	Holstein	*vituli*	10 acre pasture, brushy	In open	31	—	37	52	—[2]
	4	60	Mixed	*vituli*, *bovis*	Feed lot	Under cover	44	24	84	100	98
Toxaphene 5%	5	20	Holstein	*vituli*	Feed pen	Under cover	30	45	92	100	99+
	6	20	Holstein-Jersey	*vituli*, *bovis*	Feed pen	Under cover	23	67	98	100	100
	7	50	Holstein	*vituli*	3-acre pasture, many trees	Under cover	16	30	79	85	90
	9	42	Mixed beef stock	*vituli*, *bovis*	Feed lot	In open	18	—	57	84	—[2]
Chlordane 5%	8	55	Hereford	*bovis*	Feed pen	Under cover	31	—	94	98+	—[2]
	12	20	Holstein	*vituli*	Feed lot among oak trees	In open	18	—	72	65	—[2]
	13	50	Hereford	*bovis*	Feed lot, deep mud	In open	12	—	25	47	—[2]
	17	37	Holstein	*vituli*	Feed lot	In open	36	40	96	91	96
Methoxychlor 5%	14	58	Hereford	*bovis*	Feed lot, deep mud	In open	13	—	41	58	—[2]
	15	10	Mixed dairy	*vituli*, *bovis*	Feed lot among oak trees	In open	16	64	82	97	95
	16	23	Crossbred Herefords	*bovis*	4-acre pasture, brushy	In open	24	26	63	68	82
	18	51	Hereford	*bovis*	Feed lot on sawdust	In open	22	86	97	100	100

[1] Counts taken in ten 1-inch square areas.
[2] Cattle moved prior to check.

bon insecticides, can be used for practical control of cattle lice under Oregon feed-lot conditions. However, it is not considered to be a fully satisfactory substitute for spraying or dipping if conditions are such that one of these methods can be used. It should be mentioned that of the chlorinated hydrocarbons only methoxychlor is recommended for use on cattle being milked.

Literature Cited

Hoffman, Robert A. 1954. Self-treatment rubbing devices for louse control on cattle. Jour. Econ. Ent. **47**(4): 701.

Lindquist, Arthur W., and Robert A. Hoffman. 1954. Effectiveness of cattle-rubbing devices and hand dusting for horn fly control. Jour. Econ. Ent. **47**(1): 79–81.

Rogoff, Wm. M., and Alvin L. Moxon. 1952. Cable-type back rubbers for horn fly control on cattle. Jour. Econ. Ent. **45**(2): 329–34.

Techniques for Testing the Attachment and Feeding Rate of Mites on Living Hosts[1]

H. F. Cross and G. W. Wharton, *Department of Zoology, University of Maryland, College Park*

The techniques presented in this paper were developed to study the effects of several factors on the feeding rate of chiggers and several species of blood sucking mites. It is believed that these same techniques may also be adaptable for transmission studies.

The mites tested by these techniques were cultured in the laboratory. The two species of chiggers, *Trombicula splendens* and *Trombicula alfreddugèsi* were reared from an original stock of field chiggers, using techniques developed by Wharton (1952). The three species of blood sucking bird mites *Bdellonyssus sylviarum*, *B. bursa*, and *Dermanyssus gallinae* were cultured by techniques developed by Chamberlin & Sikes (1950). The mammalian gamasid, *Bdellonyssus bacoti*, was cultured in No. 10 tin cans supplied with wood chips and a caged mouse or hamster.

Chiggers for testing were collected from the mouth of the culture jar and placed on the surface of the water in a small finger bowl. The hair or feathers of the anesthetized host was clipped close to the skin for an area of about ½ inch in diameter. This area was thoroughly wet. Then the desired number of chiggers was placed on the wet skin with a brush. A glass vial about 3 inches in length and ¼ inch in diameter was immediately placed over the chiggers to prevent them from escaping. The vial was first clamped to a test tube clamp and this was attached to a ring stand. The open end of the vial was lowered into position over the chiggers. The pressure of the vial against the skin prevented the chiggers from escaping. After a 45-minute waiting period, the vial was removed and the chiggers on the area were counted. A comparison was made of the number on the host at the end of 45 minutes and the total number introduced. This gave the per cent of attachment.

Using these techniques, a comparison was made of the attachment rate of *Trombicula splendens* and *T. alfreddugèsi* on white mice. Twenty chiggers were used to infest each mouse in each trial. Larvae of *T. splendens* were more successful in attaching to and

[1] This investigation was supported by the Medical Research and Development Board, Office of the Surgeon General, Department of the Army, under Contract No. DA-49-007-MD-436.

Table 1.—Number and per cent of *Trombicula splendens* and *T. alfreddugesi* attached to white mice 45 minutes after infestation.[1]

	Tests with *T. splendens*		Tests with *T. alfreddugèsi*	
	First	Second	First	Second
	20	20	10	10
	16	18	11	10
	19	15	6	9
	18	18	14	7
	13	19	20	—
Total	86	90	61	36
Per cent	86	90	61	45
Grand Total	176		106	
Per cent	88		58.9	

[1] Twenty chiggers used in each trial.

feeding on white mice than those of *T. alfreddugèsi* (Table 1).

In tests to determine the biting-rate of blood sucking mites, the following technique was followed. The day preceding the biting tests, the host was killed or removed from the culture box. The mites that swarmed to the top of the box were aspirated into procaine vials which were plugged with cotton at both ends.

The mites and the cotton were pushed with a bicycle spoke into a small finger bowl surrounded by a barrier of water in a shallow dish. The dish was examined with a dissecting microscope and 10 mites of each stage to be tested were aspirated into a vial as described for the technique with chiggers. The vial had one end covered with fine-mesh silk cloth to prevent the mites from passing through the vial. After the mites were in the tube, a rubber stopper was placed in the open end. One, two or three vials of mites were clamped between a split rubber stopper containing the desired number of holes. A test tube clamp was used and the free end of the clamp was attached to a large nail in a 10 inch square board.

For the test the host was anesthetized and an area of hair or feathers removed with scissors close to the skin without injury to the epidermis. The host was then secured to the board and the vials of mites opened at one end and lowered to the skin of the host. After 30 minutes the mites on the skin and in the vials were killed with alcohol and a record maintained of the number of engorged mites. This type of test permits several species of mites or replicates of the same mite to be tested on the same host at the same time.

By this technique *Bdellonyssus bacoti* nymphs were tested on white rats at 75°, 85° and 95° F. The number of nymphs that engorged increased with each increase in temperature, but the increase was more noticeable from 75° to 85° than from 85° to 95° (Table 2). These two tests demonstrate that small differences in the behavior of mites may be detected. The size of the vial and number of mites per test may be varied for different conditions, but the use of small vials is necessary on small animals such as chicks and birds.

Table 2.—Number and per cent of *Bdellonyssus bacoti*[1] nymphs that engorged on rats at 75°, 85° and 95° F.

	Engorged			Unengorged		
	75°	85°	95°	75°	85°	95°
	0	8	10	10	2	0
	0	10	10	10	0	0
	3	10	8	6	2	0
	0	8	8	10	2	0
	3	6	10	6	4	0
	8	6	11	2	4	0
Total	14	48	57	44	14	0
Per cent	24.1	77.4	100	75.9	22.6	0

[1] Ten mites per vial.

Literature Cited

Chamberlin, Roy W., and Robert K. Sikes. 1950. Laboratory rearing methods for three common species of bird mites. Jour. Parasit. **36:** 461–5.

Wharton, G. W., aided by H. S. Fuller. 1952. A Manual of the Chiggers. Mem. Ent. Soc. Wash. **No. 4.** 185+viii.

Feeding Tests with Blood Sucking Mites on Heparinized Blood[1]

H. F. Cross, *Department of Zoology, University of Maryland, College Park*

In biting tests with mites on the skin of hosts it has been observed that a break in the skin appeared to facilitate their feeding. On the basis of this and other observations of the mechanics of feeding of *Bdellonyssus bursa* it was decided to try feeding this mite on whole blood. After several unsuccessful attempts, they were observed to engorge on blood that was absorbed in cotton. Since this original observation, a technique has been developed for feeding and also for testing the rate of feeding of mites under different conditions. The most effective method was found to be feeding through a silk cloth. The technique for testing the rate of feeding on blood was a modification of the biting test (Cross & Wharton 1954).

For this test 10 mites of each stage to be tested were aspirated into 3 inch vials $\frac{1}{4}$ inch in diameter. Silk bolting cloth over one end of the vial prevented the mites from passing through the vial. After the desired number of mites were in the vial, a piece of silk bolting cloth was placed over the open end of the tube and shoved into the tube with a hollow rubber disc of the same diameter as the inside of the tube and about 4 mm. deep.

The tubes of mites to be tested were placed under the desired conditions for a short period, then heparinized blood was introduced into the hollow of the rubber disc. The blood came into contact with the silk and the mites fed on a definite area of blood, the diameter of the inside of the rubber disc. The mites were permitted to feed for 30 minutes before completing the test. At the end of that time, the test was terminated and the number of engorged mites recorded.

[1] This investigation was supported by the Medical Research and Development Board, Office of the Surgeon General, Department of the Army, under Contract No. DA-49-007-MD-436.

Table 1.—Nymphs of *Bdellonyssus bacoti*[1] that engorged on rat blood at 75, 85, and 95 degrees F.

	Engorged at			Unengorged at		
	75° F.	85° F.	95° F.	75° F.	85° F.	95° F.
	3	8	10	5	2	0
	3	6	10	4	4	0
	3	9	10	10	1	0
	3	7	10	5	3	0
	3	5	10	7	5	0
	3	4	10	3	6	0
Total	18	39	60	34	21	0
Per cent	34.6	65	100	65.4	35	0

[1] Ten mites per vial.

Bdellonyssus bacoti nymphs were tested on rat blood at 75°, 85° and 95° F. by this technique. It was found that the rate of feeding is increased by an increase in temperature (Table 1).

Other species that fed successfully on blood were *Dermanyssus gallinae*. *Bdellonyssus bursa*, and *B. sylviarum*, and it is believed that under the proper conditions that all of these species can also be successfully reared on blood.

The amount of heparin necessary depends on the rate of feeding of the mites. Some species, under the proper conditions, can engorge sufficiently on untreated blood.

Literature Cited

Cross, H. F., and G. W. Wharton. 1954. Techniques for testing the attachment and feeding rate of mites on living hosts. Jour. Econ. Ent. 47(6): 1153–4.

Control of the Sugarcane Beetle in Corn

W. G. Eden, *Agricultural Experiment Station, Alabama Polytechnic Institute, Auburn*

The sugarcane beetle, *Euetheola rugiceps* (Lec.), did an unusual amount of damage to corn in Alabama in the spring of 1954. The injury is done by the adult beetle, which bores into the soil adjacent to the plant and feeds on the tender stem under the surface of the soil. The damage is in the form of a ragged wound which may extend farther than halfway through the culm of the plant. Young plants are usually killed; older plants may be stunted severely or fail to develop because the meristem is destroyed.

The sugarcane beetle has been known as a pest of corn in the South for many years. Phillips & Fox (1933) presented an excellent description of the life history and type of injury done by the insect which they referred to as the rough-headed corn stalk beetle. They recommended the elimination of old waste and pasture lands as well as pasturing with hogs and early plantings of corn as control measures. The Mississippi Plant Board (1926) gave similar recommendations for the control of the beetle in corn. Apparently nothing has been published on control of the beetle in corn with recently developed insecticides, therefore, an experiment with chlorinated hydrocarbon insecticides was conducted near Camden, Alabama, during the spring of 1954.

Table 1.—Injury to corn by the sugarcane beetle following insecticidal treatments.[1]

Treatments	Damage to Stalks on[2]			
	June 2		June 17	
	Per Cent	Angles	Per Cent	Angles
Untreated check	23.98	29.13	64.54	53.80
Aldrin				
0.5 lb./A., granulated	7.5	15.22	14.4	19.36
0.5 lb./A., spray	8.7	17.01	14.0	21.44
1.0 lb./A., granulated	7.4	15.05	4.8	9.02
1.0 lb./A., spray	7.4	15.66	8.8	14.54
2.0 lbs./A., granulated	5.2	12.99	5.4	11.54
2.0 lbs./A., spray	2.7	9.22	3.9	8.14
Dieldrin, 1 lb./A., granulated	13.3	20.93	20.1	26.36
Heptachlor, 1 lb./A., granulated[3]	16.4	25.39	37.5	37.72
Toxaphene, 8 lbs./A., granulated	22.4	27.58	28.0	31.73
L.S.D. at 5% level		7.45		12.76

[1] Treatment applied in eight-inch band on top of row immediately after planting on May 7.
[2] Mean of four replications.
[3] Subsequent analysis of the granules showed that only 0.03 pound of heptachlor was applied instead of 1.0 pound, as intended.

Procedure.—The experiment was conducted on corn planted May 7 in a plowed area that had been in pasture sod for several years. Two earlier plantings of corn in the field had been destroyed by the beetle.

The treatments consisted of emulsion sprays and granulated formulations applied in an eight-inch band on top of the rows immediately after the corn was planted. Aldrin was used at rates of 0.5, 1.0, and 2.0 pounds technical per acre as sprays and granules. Dieldrin and heptachlor were used at the rate of 1.0 pound per acre and toxaphene at 8.0 pounds per acre as granulated formulations. The sprays were applied with a knapsack sprayer at the rate of 15 gallons per acre. The granulated formulations (30–60 mesh) were applied by hand. The plots consisted of four rows of corn 50 feet long. The treatments were replicated four times in randomized blocks. All of the stalks in one row of each plot were examined for beetle injury on June 2 and June 17. On June 17 the corn was about 3 feet high and past danger of being killed by the beetle, so no further records were taken.

Results.—The percentages of stalks damaged by the beetle are presented in table 1. Beetle injury was severe in the untreated plots. On June 2 about 24 per cent of the stalks were damaged by the beetle. The damage continued to increase until it was more than 64 per cent on June 17.

On June 2, 25 days after the date of application, the aldrin- and dieldrin-treated plots had significantly less beetle damage than the untreated plots. Aldrin at all three rates of application, both as spray and granules, was significantly more effective than 8 pounds of toxaphene granules. There was no significant difference in the effectiveness of aldrin and dieldrin at the 1-pound rate of application; however, 2 pounds of aldrin was more effective than 1 pound of dieldrin.

On June 17 all treated plots had significantly less beetle injury than the untreated plots. The 0.5-

pound rate of aldrin had lost some of its effectiveness, and the damage in plots treated with it was not significantly less than in plots treated with 1 pound of dieldrin or 8 pounds of toxaphene. Aldrin at the 1-pound rate as granules and at the 2-pound rate as spray or granules was significantly more effective than the dieldrin or toxaphene. There was no significant difference between the effectiveness of dieldrin and toxaphene on June 17.

SUMMARY.—An experiment was conducted in Alabama in the spring of 1954 to control the sugarcane beetle, *Euetheola rugiceps* (Lec.), in corn with several insecticides. The treatments were applied in 8-inch bands on top of the row immediately after planting. Aldrin emulsion and granulated formulations were used at the rates of 0.5, 1.0, and 2.0 pounds per acre. Dieldrin was used at the rate of 1 pound and toxaphene at 8 pounds per acre as granules. Aldrin was effective at all three rates in both formulations for about 1 month after planting, after which the 0.5-pound rate began to lose its effectiveness. Dieldrin and toxaphene at the rates used were not as effective in preventing damage to corn as aldrin at either the 1- or 2-pound rate.

LITERATURE CITED

State Plant Board of Mississippi. 1926. A common corn pest. Qtrly. Bul. State Plant Bd. of Miss. **6**(1): 17–9.

Phillips, W. J., and Henry Fox. 1933. The roughheaded corn stalk beetle in the southern states and its control. U.S.D.A. Farm, Bull. **875** (rev.).

Table 1.—Control of the army cutworm with insecticides at Manhattan, Kansas, April, 1, 1954.

TREATMENT	TOXICANT PER ACRE (Pounds)	LARVAE PER SAMPLE[1]	PER CENT CONTROL[2]
Untreated	—	2.15	—
Endrin	0.2	0.25	88
Endrin	0.1	0.25	88
Dieldrin	0.25	0.40	81
Aldrin	0.25	0.60	72
Aldrin	0.5	0.40	81
Heptachlor	0.25	0.45	80
Heptachlor	0.5	0.35	84

[1] Average of 20 samples, each 1 square foot in area.
[2] Twelve days after treatment.

Table 2.—Control of the army cutworm with insecticides near Alma, Kansas. March 31, 1954.

TREATMENT	TOXICANT PER ACRE (Pounds)	LARVAE PER SAMPLE[1]	PER CENT CONTROL[2]
Control	—	1.8	—
Aldrin	0.5	0.25	86
Dieldrin	0.25	0.4	78
Endrin	0.2	0.2	89
Heptachlor	0.5	0.4	78
Toxaphene	2.0	0.6	67

[1] Average of 20 samples, each 1 square foot in area.
[2] Nine days after treatment.

Control of Army Cutworms[1]

C. C. BURKHARDT[2]

The army cutworm, *Chorizagrotis auxiliaris* (Grote), is locally of major importance in Kansas each year. It occurred in threatening numbers in many fields of seedling alfalfa in local areas in Clay, Cloud, Jewell, Ottawa, Republic, Riley and Wabaunsee counties in March 1954 where larvae per square foot ranged from 0 to 12, averaging 5 per square foot in many fields. Cutworms were also present in many of the wheat fields and established stands of alfalfa but caused noticeable damage only in seedling alfalfa and severe injury to bromegrass in a few cases.

Insecticide test plots were established in alfalfa in two areas. The small plot tests were conducted on the Kansas State College Agronomy Farm near Manhattan. Field test plots were established on a farm near Alma, in Wabaunsee County.

METHODS.—Small plot tests in alfalfa on the Agronomy Farm consisted of rod-square plots, each replicated three times, with the exception of those for heptachlor. The materials[3] tested included aldrin, endrin and heptachlor at two rates each and dieldrin at one rate as shown in table 1. These were applied with a Hudson 3-gallon hand sprayer with about 30 pounds of pressure, applying ½ gallon of total emulsion per square rod plot. Applications were made during late afternoon March 20.

Field plots near Alma were 1 acre in size, nonreplicated. Aldrin, dieldrin, endrin, heptachlor and toxaphene were applied at 0.5, 0.25, 0.2, 0.5 and 2 pounds of toxicant per acre, respectively. Application was made through a regular boom-type weed sprayer, dispersing approximately 5 gallons of emulsion per acre, during the late afternoon of March 22. A control plot was left untreated.

The army cutworm population consisted largely of fourth-instar larvae at the time of application of insecticides, which coincided with the period during which farmers were making applications.

RESULTS.—Relatively cool weather with maximum temperatures of 44 to 50°F. dominated the period between applications and dates of observation. Results were recorded April 1 (12 days after treatment) on the Agronomy Farm plots (Table 1) and March 31 (9 days after treatment) on the Alma plots (Table 2). A total of 20 1-square-foot samples were taken from each treatment. Populations appeared evenly distributed in these plots. Endrin produced 88 per cent control regardless of rate of toxicant applied per acre. Satisfactory results were obtained with heptachlor (84 per cent) and aldrin (81 per cent) at 0.5 pound of toxicant per acre and with dieldrin (81 per cent) and heptachlor (80 per cent) at 0.25 pound of toxicant per acre.

The results of 20 1-square-foot samples taken from each of the Alma plots are shown in table 2. The population was also evenly distributed in these

PAID PAPER.
[1] Contribution No. 637 Department of Entomology, Kansas Agricultural Experiment Station, Manhattan. Studies conducted under Restricted Fees Project 100.
[2] Assistant Entomologist, Kansas Agricultural Experiment Station, Manhattan.
[3] Materials supplied as follows: aldrin, dieldrin and endrin by the Shell Chemical Corp., Denver, Colo.; and heptachlor by the Velsicol Corp., Chicago, Ill.

plots. Endrin at 0.2 pound of toxicant per acre was the most effective (89 per cent), followed by aldrin at 0.5 pound (86 per cent), dieldrin at 0.25 pound and heptachlor at 0.5 pound (78 per cent), and toxaphene at 2 pounds (67 per cent).

There were only small differences in control obtained with applications of 80 gallons emulsion per acre in the small plot tests, or 5 gallons of emulsion per acre in the field tests.

SUMMARY.—Insecticide test plots to control the army cutworm in alfalfa in Kansas in March 1954 consisted of rod-square plots treated with hand equipment at the Agronomy Farm near Manhattan and field plots 1-acre in size near Alma.

Endrin gave best control in both experiments, with 88 per cent control in the small plots at 0.1 or 0.2 pound of toxicant per acre and 89 per cent control in the acre-plot at 0.2 pound per acre. Control ranging from 80 to 84 per cent was obtained in the small plots with aldrin or heptachlor at 0.5 pound actual toxicant per acre and dieldrin or heptachlor at 0.25 pound. In the acre-plots, aldrin ranked second, producing 86 per cent control at 0.5 pound per acre of actual toxicant. Dieldrin at 0.25 pound or heptachlor at 0.5 pound gave 78 per cent control. Toxaphene at 2 pounds of toxicant per acre produced 67 per cent control.

The Yellow Clover Aphid—A New Alfalfa Pest in the Southwest[1]

D. M. TUTTLE and G. D. BUTLER, JR., *Arizona Agricultural Experiment Station, Tucson*

The yellow clover aphid, *Therioaphis ononidis* (Kalt.) has long been known as a minor pest of clover in central and eastern United States (Folsom 1909, Davis 1914). It was not known to occur in the southwest until damaging infestations were discovered on alfalfa at various points in Southern Arizona during May and June, 1954. In the Cooperative Economic Insect Report, issued by the United States Department of Agriculture, this aphid has since been reported in 1954 from New Mexico and in the Imperial Valley of California. Dr. R. C. Dickson of the Citrus Experiment Station, University of California, determined specimens from Arizona as *Therioaphis ononidis*. This species has also been reported in the literature as *Callipterus trifollii* Monell, *Myzocallis trifolii* (Monell) and *M. ononidis* (Kalt.). The life history, habits and appearance of the various forms of the species are described by Davis, 1914.

At Yuma, Arizona, nymphs and adults were found on the lower surfaces of alfalfa leaves. The lower leaves were the first to be infested, soon became dry and were shed. Hay yields were reduced and hay quality was lowered by the increased ratio of stems to leaves. In heavily-infested fields an abundance of honeydew on the leaves, stems, and ground made baling of hay difficult or impossible. The quality of the hay was further affected by the rapid spread of a black fungus over the surfaces covered with honeydew. There were preliminary indications in 1954 that injured alfalfa plants showed retarded re-growth after hay cutting and that seed yields were reduced. No parasitized aphids of this species have yet been observed in Arizona.

CONTROL TESTS.—In table 1 are summarized the results of two tests in which insecticidal dust formulations were applied to irrigated alfalfa grown for hay in the sandy Yuma Mesa district near Yuma, Arizona. All dusts in both tests were applied with a Hardie tractor-mounted duster with a 30-foot boom. In each test the plots were 1 acre in extent with four replications for each treatment.

Table 1.—Insecticide tests against the yellow clover aphid on alfalfa, Yuma, Arizona, 1954.

Insecticide Dust	Aphids per 100 Net Sweeps After Days Indicated				Pounds of Hay Per Acre
	2	4	8	12	
	Test 1[1]				
5% malathion	109	18	21	8	—
10% malathion	12	26	116	15	—
5% *Chlorthion*	149	2	107	6	—
25% methyl parathion	45	20	114	1	—
5% DDT, 15% toxaphene plus 40% sulfur	19	7	46	16	—
10% DDT	323	119	209	16	—
1.5% lindane	97	109	229	14	—
untreated	441	696	457	207	—
L.S.D. at 5% level	77	206	127	—	—
at 1% level	104	280	173	—	—
	Test 2[2]				
5% malathion	8	43	8	—	1278
2% parathion	55	130	0	—	1265
5% DDT, 15% toxaphene plus 40% sulfur	236	17	2	—	1243
5% DDT, plus 15% toxaphene	78	58	8	—	1128
20% toxaphene	913	273	0	—	959
99% sulfur	191	13	6	—	1015
4% Diazinon	241	67	0	—	1200
Untreated	6200	1771	24	—	763
L.S.D. at 5% level	396	502	—	—	130
at 1% level	538	683	—	—	185

[1] Dusts applied June 28 at 25 pounds per acre.
[2] Dusts applied July 6 at 18 pounds per acre.

The results show that the yellow clover aphid may be effectively controlled on alfalfa by a number of different insecticides. For hay crops phosphate insecticides, such as malathion, parathion, *Chlorthion*, methyl parathion, and Diazinon are promising because of their relatively short-lived residues. The general use of such materials on alfalfa grown for hay is subject to the approval of the Pesticide Regulation Section of the U. S. Department of Agriculture. Alfalfa grown for seed may be protected against the yellow clover aphid and other harmful insects by formulations of DDT and/or toxaphene with sulfur, although further tests are needed to firmly establish the simplest and most effective formulations.

LITERATURE CITED

Davis, J. J. 1914. The yellow clover aphis. U.S.D.A. Bur. Ent. Tech. Ser. **25**: 17–40.

Folsom, J. W. 1909. The insect pests of clover and alfalfa. Ill. Agr. Expt. Sta. Bul. **134**: 175–8.

[1] Arizona Agricultural Experiment Station Technical Paper No. 343.

Effect of Planting Date on Corn Earworm Damage to Dent Corn

W. A. DOUGLAS, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

Tests to determine the best planting date for dent corn to avoid injury by the corn earworm, *Heliothis armigera* (Hbn.), were conducted from 1945 to 1948 at State College, Mississippi. The susceptible open-pollinated variety Jellicorse was used. Eight planting dates were set up, beginning on March 1 and ending on June 15, plantings being made at 15-day intervals. Bad weather prevented the planting of corn on the first three dates in 1945 and on the first date in 1948. The corn was planted in rows with a hand planter, two stalks to the hill, 40 inches apart on 100 foot rows. The test corn was planted close to other corn so that the plants were exposed to natural earworm infestation and entered into competition with other corn when planting dates corresponded with those of adjacent fields, There were four replications in 1945, eight in 1946, four in 1947 and two in 1948. The plots were randomized so that none would be favored by their proximity to other corn.

The corn was harvested in October, and a hundred ears were taken from each replication on each planting date. The ears were then rated individually for earworm damage, and an average damage rating was obtained for each date of planting. The percentage of infested ears in each plot was also determined.

The data obtained are given in table 1. The plots planted on April 1 and 15 and May 1 were damaged the least by the corn earworm. Very little corn was planted in the neighborhood before April 1 to provide silks that would compete for earworm eggs with those in the March-planted plots. The heaviest damage, in the last three plantings, was probably due to a concentration of moths and egg laying in the plots. Presumably, in the April and May 1 plantings the moths were dispersed over a large area and therefore laid fewer eggs on the silks in the plots. Actually, most of the dent corn in Mississippi is now planted in April.

The percentage of infested ears was generally proportional to the rating of earworm damage. The quality of the corn was much better in the midseason than in the early or late plantings. The earliest planted corn was somewhat damaged by birds and had the highest infestation of the rice weevil, *Sitophilus oryza* (L.). The last two plantings were injured more by diseases than the early or midseason ones.

Table 1.—Damage rating[1] and per cent of ears infested with the corn earworm in Jellicorse dent corn planted on different dates at State College, Miss., 1945–1948.

Planting Date		1945		1946		1947		1948		Average	
		Damage Rating	Per Cent of ears Infested	Damage Rating	Per Cent of ears Infested	Damage Rating	Per Cent of ears Infested	Damage Rating	Per Cent of ears Infested	Damage Rating	Per Cent of ears Infested
March	1	—	—	2.09[2]	79[2]	2.82	94	—	—	2.46	86
	15	—	—	1.72	73	2.51	91	2.84	96	2.36	86
April	1	—	—	1.33	59	2.41	92	2.54	96	2.09	82
	15	2.36	90	1.84	63	2.44	88	1.84	80	2.12	80
May	1	1.95	78	1.51	61	2.62	92	2.69	97	2.19	82
	15	2.55	87	2.18	80	2.80	96	3.01	99	2.64	91
June	1	3.16	98	3.13	99	3.09	99	2.80	98	3.05	98
	15	3.17	98	3.21	98	3.22	99	2.96	99	3.14	99
L.S.D.	5%	0.19	4.7	0.27	16	0.22	3	0.27	7		
	1%	0.27	6.6	.36	21	.30	4	.41	10		

[1] 0 (no damage) to 5 (severe damage).
[2] Three replications not harvested.

BOOK REVIEW

THE PESTS OF FRUITS AND HOPS, (3rd edition, entirely revised) by A. M. Massee. Crosby Lockwood & Son, Ltd., 26 Old Brompton Rd., London, S. W. 7., 1954; xvi+338 pages, 32 plates. Price 25s net.

Dr. Massee's well known manual "The Pests of Fruits and Hops" has long been the standard reference for information on pests of fruits, berries, nuts and hops in England. The latest (third) revision by Dr. Massee brings up to date the information needed to recognize and combat them most economically and effectively. The occurrence throughout the book of recommendations for use of the newer insecticides, particularly DDT and BHC, and the information included on the newer insecticides and on spray machinery indicate the marked advances that have occurred in fruit pest control in England in recent years and the completeness of the revision that brings it as currently up to date as present day rapid advances will permit. It is of interest that developments in control arising from the availability of the newer, highly effective insecticides and improvements in spray machinery have completely transformed spray programs recommended for protecting fruits, berries, nuts and hops from insects and mites in England, as in the United States.

This manual is a concise and effective presentation of a summary of knowledge of the pests covered. Pests are taken up by crops and, under each crop, in a regular order based on taxonomic groupings, as beetles, moths, sawflies, etc. There is information on each pest under the headings "Recognition in the Field," "Notes on Life Cycle," and "Control Measures."

Dr. Massee's book is primarily a practical manual for growers of fruits, berries, nuts and hops in England and is certain to continue to be generally accepted for such use. It should also be of interest, in a general way, to technical workers and others interested in pests of those crops in other countries.

HOWARD BAKER

EDITORIAL

Systematic Entomology—Retrospect and Prospect

A periodic analysis is necessary in most fields of endeavor. Without a review of progress made, followed by an assessment of present trends, there is no basis for the proper alignment toward future objectives. Dr. Knipling, in a recent editorial in this JOURNAL, has reviewed the status of the broad field of entomology. A similar analysis is essential in systematic entomology, which is playing an increasingly important part in professional entomology. It is a living, expanding science, which is becoming more and more a study of living populations rather than one of dead, individual specimens. Such an analysis is especially appropriate at this time as the second century of professional entomology in the United States begins.

The entomologists who in 1854 were appointed to the earliest positions were not hired as taxonomists. But they must have found it necessary to discriminate between harmful and beneficial insects. The knowledge permitting them to do so resulted from their own observations and the recorded statements of investigators of taxonomic questions; such men as LeConte will never be forgotten in the history of systematic entomology. By 1854 LeConte had been publishing on the taxonomy of beetles for 10 years, and he was one of a goodly number of men with interests covering many groups of insects.

Those must have been exciting days. Practically every sample of specimens contained undescribed species and genera, and many of them new families as well. LeConte created few synonyms. The field was so vast he could hardly do so. Nor did he content himself with mere descriptions. His broader studies on the classification of Coleoptera are scarcely surpassed today. However, I should like to make one comment without detracting from his stature in any way. Although most of his species are good, all the specimens of a series standing under one name in his collection are not necessarily of the same species. We still have mixed series today, but I believe they are less frequent than they were a century ago, and my belief is based on a conviction of progress in systematic entomology since the period when LeConte was active.

Taxonomists of a century ago had "tools" of the profession quite comparable to ours although certainly less well refined. We use fewer hand lenses. We have better catalogues to the literature for nearly all groups. We have more adequate collections, which are readily available to qualified students. We have more stringent but evidently necessary rules of nomenclature. These are all signs of what might be termed "material progress," but they do not reflect my interpretation of basic progress. I believe such progress lies in the growing realization of the bearing of many branches of science on taxonomy, in an increase in the responsibility of the investigators, and in a change of emphasis from the immature exultation of finding and describing new species to the sobering realization that our great task is to understand and interrelate the species already described as well as the undescribed ones as they are encountered. Successful attainment of such a goal is possible only after painstaking examination and interpretation of data acquired by application of related sciences to the problem.

The change in approach to taxonomic problems has not been sudden and well marked. It had its beginning well back in the 19th century, but it did not gain noticeable momentum until much later. It has brought the realization that the purely morphological definition for a species is not enough. There must be a broader definition which takes into consideration other factors, such as ecology, physiology, genetics, and geographical distribution. However, we can not disregard the morphological basis for separation of species. It will remain indispensable for practical use.

An example of the change in outlook is found in the study of immature insects. Before 1900 an insect was usually considered worthy of study only when it was mature. Little interest was apparent in the larva or nymph from which the adult developed. The significance of types of

metamorphosis and its bearing on basic relationships was recognized by Brauer in the 1880's. There were separate works on larvae, such as Schiodte's great study of beetle larvae. But there was no general realization of the value of a knowledge of immature insects. At the present time correlated studies of the immature stages and the adults are made in almost all groups of insects. More and more courses covering the subject are being offered at colleges and universities. Such a broadening of interest will give a better understanding of each kind of insect as a living entity, for information on an insect in any one stage, be it every so complete, can not compare with information on the insect in all its stages. A correlation of these facts with data on other factors, as mentioned earlier, must bring strong convictions on the relationships of species. What an insect feeds on and how it feeds; how it walks, flies, or swims; how and where it builds its nest (if it does); and what areas of the earth it inhabits—all these characteristics show evolutionary trends as much as do structural developments, and are taken into account in basic systematic study. Furthermore, and significantly, information on them is sought by economic entomologists with increasing frequency. The simple, but not always easily supplied, answer to the question "What is it?" is no longer the limit of a taxonomist's information.

I do not mean to infer that our knowledge of all groups of insects is complete. This is far from the truth. Many families in the Coleoptera—and I am sure in other orders as well—are very poorly known because of the small size of the individuals or the economic obscurity of the species. In those groups the basic understanding of the species is much as it was a century ago.

As to the future in insect taxonomy, there are some definite trends that are worthy of consideration. The increase in the number of courses on immature insects offered at educational institutions will obviously strengthen the awareness that a species is more than a series of pinned adults. The very act of collecting immature insects will introduce the student to observations on ecology and behavior. Those students who become taxonomists will take ecology, behavior, and other factors into consideration in their revisionary works. In practical taxonomy identifications for species in any stage will be the responsibility of one individual. Keys that use characters of any or all stages will appear more often. Examples are Crowson's current paper on the families of Coleoptera, and one on the black flies of New York will be published soon.

I should like to see, in the not-too-distant future, new species described only when considerable information is available on developmental stages as well as on the mature insects. I wonder what the present status of our knowledge of immature insects would be if that method had been in vogue for the past century. It would have forced the rearing of species and correlation of the various stages, and could not fail to have increased the knowledge of biology. Fewer species, by far, would have been described and the number to be described would be correspondingly greater. On the other hand, there would have been fewer synonyms and, on the whole, insect taxonomy would have benefited.

In the study of comparative behavior only a start has been made. Evans in a recent article reviewed investigations of the behavior of spiders, crustaceans, mantids, termites, crickets, vinegar flies, and certain groups of Hymenoptera. It is obvious that much more progress will be made in coming years. But it will not be done with present staffs. The field is immense, and observations that are to be made and correlated with other factors need large numbers of investigators.

For the future there is no foreseeable diminution in the need for identification of insects. The basis for requests for names is broadening. More people are asking for accurate naming of pests, be they household or agriculture. The demands can soon surpass the ability of staffs of institutions to cope with the flood. Little time will be left for identifications of samples of uncommon species, those that require special preparations or techniques, or for research to uncover their distinguishing characteristics. There can be only one solution. More individuals must put more time on research. The amount of information that has been gathered, published, and catalogued compared with that still to be uncovered is pitifully small.

The future of collections in museums is

worthy of some speculation. A rough estimate would place the number of specimens in museums in the United States at close to 40 million. It might appear that such a number would be sufficient to meet requirements by taxonomists. But for only a small percentage of our species are there adequate series, and most of them represent only one developmental stage. When we consider the need for samples of eggs in situ, immature stages in the various instars, pupal cases or cocoons where they are formed, and feeding evidence, we see of what a truly representative collection should consist. However, most museums are already crammed with essential material. Where and how the collection will be stored and who will care for it I don't know. But we must gather and study such a collection if we are to furnish satisfactory names for insects in any stage and supply answers to the increasing number of queries for other basic information on insects.

A serious problem for taxonomists, in the Federal Government at least, is to find time to do research that will lead to a more intimate knowledge of species, such as gathering information on biology and ecology, when their time is filled with supplying demands for identification of dead, dried, and occasionally crushed insects. One solution to this problem is to have it understood that the duties of a systematist include considerable field work gathering data for answering definite taxonomic questions.

A second solution, probably inferior to the first in the proper utilization of trained personnel, requires a division of labor in investigations of taxonomic problems. Such a split should be similar to that in economic entomology, where certain groups of men are responsible for research on the control of insects and others for the application of the control, but in insect systematics there should be a single compact organization. In it one group of investigators will have little call on their time to make identifications. They will investigate the insects as living entities—when, how, and where the eggs are laid; the development of the immature stages; relationships with the host whether it be plant or animal; reactions to stimuli; and so forth. When this information is acquired and correlated, the separation of the species on morphological characters can be reëvaluated. The information will then be ready for use by a second group of men, who will furnish names for collected samples and maintain museum collections. They will indicate the difficult genera- or species-complexes, in which field work is needed. This second group will have no concern over the need for their services. Routine identifications can never be made by using cytological, histological or physiological methods, at least not to a practical degree.

I realize that any expectation of an immediate increase in the number of investigators throughout the United States —at least, any increase that will make possible appreciable progress along the trends I have indicated—must be balanced against the requirements for research along other lines of entomology. The need for such an increase should be obvious, however, and is worthy of serious consideration in the early years of this second century of professional entomology.

W. H. ANDERSON,
Entomology Research Branch,
Agricultural Research Service,
United States Department of Agriculture

OBITUARIES

Harry Frederic Dietz
1890-1954

The many friends and professional acquaintances of Harry F. Dietz were shocked by the sudden death of this able scientist on September 4. Apparently in excellent health, Dr. Dietz was stricken with a fatal heart attack at his home near Kennett Square, Pennsylvania.

Harry Frederic Dietz was born at Indianapolis, Indiana on December 8, 1890. An early interest in botany stemming from a boyhood job in the greenhouses of a local florist was encouraged by stimulating courses in biological sciences at Shortridge High School and confirmed at Wabash College. After 2 years at Wabash, he transferred to Montana State College to accept a student assistantship at the Montana Experiment Station. Here he worked on vectors of Rocky Mountain spotted fever and other problems. Recalled to Indiana by family illness, he resumed his academic training at Butler College. Upon graduation with a B.A. degree in zoology in 1914, he began a two-year period of service as deputy state entomologist of Indiana. Although concerned with inspection work and other routine duties, he found time to engage in his taxonomic interests on scale insects. There resulted from this study a taxonomic classic, "The Coccidae or Scale Insects of Indiana," which appeared as pages 195–321 of the Eighth Annual Report of the Indiana State Entomologist. Dr. Dietz always regarded this work, coauthored by Harold Morrison and beautifully illustrated by R. E. Snodgrass, as his major contribution to scientific literature.

HARRY F. DIETZ

Dietz left Indiana at the end of 1916 to accept a position as entomological inspector for the Federal Horticultural Board. He was stationed in the Canal Zone for 2 years working on insect pests of ornamental plants and sub-tropical fruits. One of his major assignments was the study of citrus black fly. The results, published in collaboration with James Zetek in U.S.D.A. Bureau of Entomology Bulletin 885, still form the basic knowledge of the biology of this important pest. His experience also resulted in a publication with T. E. Snyder on biological notes on the termites of Panama. Returning to the U. S. in 1919, Dietz was engaged in plant quarantine and inspection work in Washington, D.C. He often called on his vivid memory for recollections of work with C. L. Marlatt and other entomologists of the day in Washington. Dr. Dietz left the U.S.D.A. to return to Indiana as Assistant State Entomologist where he spent 10 happy years in association with Frank Wallace, long-time Indiana State Entomologist.

It was typical of Harry Dietz that he always maintained an interest in new problems and was eager to advance his field of knowledge. At an age when most men are settled in their profession, he entered the Ohio State University in 1929 to pursue graduate studies. Working both on the campus at Columbus and at the Ohio Experiment Station at Wooster, he earned the degree of M.A. in entomology in 1930 and the Ph.D. in 1931.

In 1932 Dr. Dietz accepted a field research position with the Grasselli Chemicals Department of the du Pont Company at Wooster, Ohio where he conducted insecticide investigations until transferred to the Du Pont Experimental Station at Wilmington in 1936. Since 1949 he had been Manager of the Agricultural Chemicals Section. His wide knowledge of field conditions, plant ecology, the life history of injurious insects and plant diseases and plant culture made him invaluable in the development of new agricultural chemicals. He played a prominent part in the development and introduction of many products including the fixed copper fungicides, the dithiocarbamates, thiocyanates, DDT, methoxychlor, BHC, ammonium sulfamate, 2,4-D, and the substituted urea herbicides.

As a result of his experience in state, federal, and industrial work, Dr. Dietz had an unusually wide circle of acquaintances in the biological field. His genuine interest in people and in scientific problems made him a welcome visitor wherever he went. His friends will remember especially his boundless vitality and amazing memory. More than most men, Harry Dietz was "a part of all that he had met." Wherever he worked or lived, he found things of interest to add to his store of knowledge. His brilliant mind, inquiring spirit and sincere interest in new developments fitted him admirably for research pursuits. His close associates remember and miss his ever-ready help in the routine problems of everyday research and living. To work with him was a privilege and an inspiration.

Dr. Dietz was an exceedingly versatile man, not only being well qualified in the various branches of entomology; he was also a skilled botanist and well

versed in plant pathology, weed control and many associated disciplines. His interest in nature and growing things transcended his practical work, and he was an avid student and observer of nature. He was, in fact, one of the vanishing race of old-school naturalists who loved, appreciated, and understood nature as an entity and not as a series of compartmented specialties. His hobby was ornamental horticulture and his country home was a veritable park of well kept shrubs, trees, and beautiful flowers. His authoritative knowledge in horticulture was attested by his honorary membership in the National Association of Gardeners. He was especially interested in iris, peonies and in recent years in lilies and azaleas.

Dr. Dietz was a member of the Entomological Society of America (A.A.E.E.) for nearly 40 years and was Chairman of the Eastern Branch in 1946. Other scientific societies of which he was a member included the American Association for the Advancement of Science, the Indiana Academy of Science, the Ohio Academy of Science, and Sigma Xi.

Dr. Dietz was married in 1914 to Dorothy Hills Dietz, who survives him. Mrs. Dietz, herself a skilled gardener, complemented his interest in flowers. He is also survived by 4 sons and 13 grandchildren.

S. S. SHARP

Sherman Weaver Bilsing
1885-1954

Sherman Weaver Bilsing was born December 8, 1885, and reared on a farm near Crestline, Ohio. He taught in the public schools of Ohio at the age of 17 before he finished high school. His high school training was completed at Martin Bolhm Academy in 1908. In 1912 he received the Bachelor of Science Degree from Otterbein College and the Bachelor of Arts Degree from Ohio State University. Dr. Bilsing was a Fellow at Ohio State University in 1912–13, receiving the Master of Arts Degree in 1913. He spent the summer of 1915 studying entomology at the University of California. Dr. Bilsing came to the Texas Agricultural and Mechanical College as Instructor of Entomology in 1913 and was appointed Acting Head of the Department in 1915 and was made Head of the Department in 1918, in which capacity he served until 1947. He continued to serve as Professor of Entomology at Texas A. & M. College from 1947 until his retirement in October, 1952, after more than 39 years of devoted service to the State of Texas and to professional Entomology. He returned to Ohio State University in 1923–24 on a University Fellowship and received his Doctor of Philosophy Degree in 1924. Although Dr. Bilsing had been in failing health for several years, his death on July 23, 1954, came as a shock to his co-workers and many other friends.

Dr. Bilsing was married to Miss Alma Merwin of Mt. Vernon, Iowa, on August 22, 1922. Mrs. Bilsing and a son, William Albert, a practicing physician, survive. Another son, Dean, preceded him in death, December, 1932.

For many years he furnished the inspiration for his students to pursue advanced training in the field of entomology. He gave liberally of his time to those in need of council and his guidances were accepted and cherished by many who followed them. Graduate and former students have marvelled at his ability to remember names and faces and his keen mind

SHERMAN W. BILSING

was always filled with many incidents that occurred throughout his teaching career. He was responsible for making financial arrangements for many undergraduate and graduate students in pursuit of college education. Many personal loans were made to students, and in most instances, with absolutely no security. When asked why he did not require a signed note, he responded, "I would not loan the money if I thought your word was not better than a note." An outstanding characteristic was his ability to obtain the respect and devotion of those fortunate enough to have studied under his guidance. He trained several of the outstanding entomologists in the nation. Above all things, he was a man; true, dependable, lover of the truth and a real scientist.

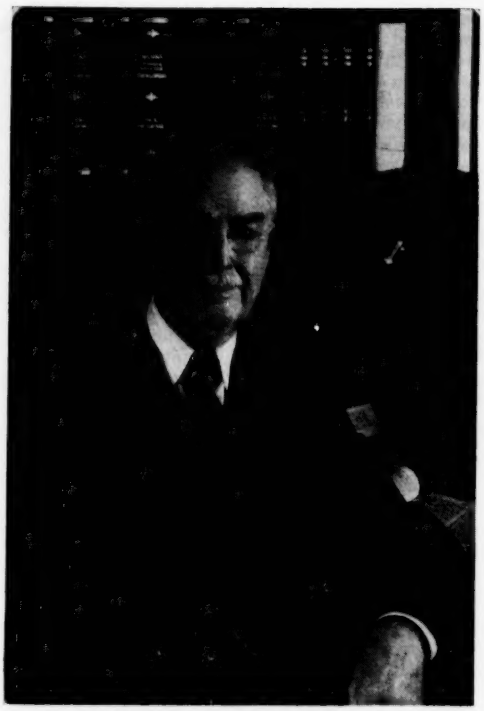
Dr. Bilsing was a believer in, and supporter of, the various professional societies of Entomology. He was a Fellow of the American Association for the Advancement of Science, and of the Entomological Society of America. He was an Honorary Life Member of the Texas Academy of Science. Dr. Bilsing was given the Distinguished Service Medal and made an Honorary Life Member of the Texas Pecan Growers' Association in 1928 for his contribution to the pecan industry through insect control. He helped organize and served as the first President of the Texas Entomological Society which is now the Southwestern Branch of the Entomological Society of America.

Dr. Bilsing held various offices in professional societies, among them the Secretary of the Academy Conference of the American Association for the Advancement of Science from 1928 to 1941, Vice-Chair-

man of this conference from 1941 to 1944 and Chairman in 1945–1946. He was a member of the Executive Council of the AAAS from 1928 to 1944. In the American Association of Economic Entomologists he was Chairman of the Membership Committee in 1931, Vice-President of the Section on Beekeeping in 1936, First Vice-President of the Association in 1937, Chairman of the Cotton States Branch of the AAEE in 1935, Secretary of the Section of Teaching of AAEE in 1941 and Vice-President of this section from 1941 to 1945. He was a representative of the Texas Academy of Science to the American Association for Advancement of Science from 1928 to 1944. He was a member of Sigma Xi and Pi Kappa Delta. Dr. Bilsing was librarian for the Texas Academy of Science and in which capacity he served for many years.

"Doc," as he was referred to by his students, was more than just a classroom professor. He was the first entomologist to do extension work in Texas under the Smith-Lever Act. He was consulting entomologist during 1927 for insurance companies whose clients were exporters of flour. He maintained a continuous research program and did outstanding work on the biology and control of several insects. He was the author of many scientific bulletins and papers. His most well known publications were those pertaining to the life history and control of the pecan nut casebearer. His research on this insect is one of the most thorough studies ever made on any insect, including biological studies of such insects as the cotton boll weevil and codling moth.

D. F. MARTIN
M. A. PRICE
N. M. RANDOLPH



HERBERT OSBORN

Herbert Osborn
1856-1954

Professor Herbert Osborn, a pioneer leader in entomology, died at the age of 98, on September 20, 1954, as a result of a stroke suffered 5 weeks before.

He was born March 19, 1856 in Lafayette Township, Walworth Co., Wisconsin. Ancestors on both sides were of New England blood, and both of his parents were natives of Massachusetts. His father, Charles Paine Osborn, went west to Wisconsin in 1840 and 4 years later married Harriet Newell Marsh. Herbert was the third child in a family of four.

When he was 7 years old, his family moved to Fairfax, Iowa, frontier, unfenced prairie land, environment opportune for the development of a naturalist because of the abundance of wild life. His innate interest in natural science was expressed publicly when at the age of 15 he became a taxidermist and won a prize of 50 cents at a county fair exhibiting a case of "stuffed" birds.

Attendance at Grinnell College, Iowa, was brief because of illness and the "Depression of 1873" delayed further college work until 1876, when he entered Iowa Agricultural College, now Iowa State College. He graduated with a B.Sc. in November, 1879, having taught school during winters to secure funds for college attendance, and continued there to receive an M.Sc. in 1880.

Starting the day after graduation, as an assistant in the College, he became a professor in 1885, Entomologist of the Iowa Experiment Station in 1890 and State Entomologist in 1898. He served in the U. S. Division of Entomology as field agent 1885 to 1894.

He moved to Ohio in 1898 to assume the position as Head of the Department of Zoology and Entomology at The Ohio State University, a position held until 1916 when he became one of the first Research Professors at the University. In 1933 he was retired as Professor *Emeritus*.

In 1912 he helped organize the Ohio Biological Survey and acted as its Director until his death. In addition he directed Ohio State's Lake Laboratory at Sandusky on Lake Erie from 1898 to 1918, and for many years was associate entomologist at the Ohio Agricultural Experiment Station. He served as consultant to the Maine Experiment Station and to the Tropical Plant Research Foundation of which he was a trustee.

Professor Osborn held honorary doctorates from Iowa State College, The University of Pittsburgh and The Ohio State University. He was a member of numerous scientific organizations, serving as president of the Iowa Academy of Science in 1887; the Ohio Academy of Science in 1905; The American Microscopical Society, 1909–11; the Entomological Society of America, 1911; and the Society for the Promotion of Agricultural Science, 1916–17. He was vice-president of the American Association for the Advancement of Science in 1917 and chairman of the Zoological Section, and in 1907–08 was national secretary of the scientific honor society, Sigma Xi. He was a life member of the California Academy of Sciences and the Societe Entomologique de France.

He was an honorary member of the former American Association of Economic Entomologists, and also of the Entomological Society of Washington to which he had paid dues for more than fifty consecutive years.

He traveled in Europe, first in 1894 when he went to Naples to use the Smithsonian Table at the Naples Zoological Station. Later he attended International Congresses of Entomology at Brussels, Oxford and Paris.

In 1892 he traveled into Mexico as far as Tehuantepec, and in 1909–10 visited most of the states for collection of insects with a commission from the U. S. Bureau of Entomology.

In 1893 he had charge of the entomological exhibit of the U. S. Experiment Station at the World's Fair. He collected extensively, expecially Homoptera, and the Herbert Osborn Collection which contains many types, was donated to The Ohio State University in 1934. His valuable library has been willed to the University.

Two principal interests, economic entomology and systematics of hemipteroid insects, especially leafhoppers, appear on examination of his bibliography. Starting with publication of his first scientific paper in 1879, he produced more than three hundred papers for scientific journals. His books include: "Insects Affecting Domestic Animals" 1896; "Economic Zoology" 1908; "Agricultural Entomology" 1916 and (after retirement) "Fragments of Entomological History," Part I, 1937; Part II, 1948; "Meadow and Pasture Insects" 1939; and "A Brief History of Entomology" published in 1952.

He served as editor of the Proceedings of the Iowa Academy of Science, the Ohio Journal of Science, and the Annals of the Entomological Society of America.

Professor Osborn married Alice Isadore Sayles of Manchester, Iowa, a graduate of Iowa Agricultural College, in 1883. Mrs. Osborn died in 1939. Five children, fourteen grandchildren and six great-grandchildren survive. The children are Dr. Morse F. Osborn of Columbus, Ohio; Dr. Herbert T. Osborn of Davis, California; Evelyn, Mrs. C. M. Knapp of Kent, Ohio; Dorothy, Mrs. Halsey Bagg of Yorktown Heights, New York; and Margaret, Mrs. Myron Lounsbury of New York City.

Always temperate in his habits, conservative and persistent, he enjoyed excellent health. He was gifted with a remarkable memory and superb eyesight. He was able to see with his hand lens parts of insects for which the rest of us required a microscope.

Professor Osborn inspired unusual enthusiasm for scientific work from a great number of students, many who became leaders in the field. This has been called his greatest contribution to entomological science. We noticed that he kept his office door ajar, especially when meetings were held, or new students arriving, and gave each of his visitors a cordial welcome. Hale and hearty at 96, he reported twice weekly to his Ohio Biological Survey office on the campus.

He was a member of the First Congregational Church of Columbus.

He will be remembered with affection by all those fortunate enough to have known him personally and known by all entomologists through his work.

DOROTHY J. AND JOSEF N. KNULL

BOOK REVIEW

STATISTICS AND MATHEMATICS IN BIOLOGY, by O. Kempthorne, T. A. Bancroft, G. W. Gowen, and J. L. Lush, Iowa State College Press, Ames, Iowa. 1954. 6×9 inches, 632+ix pages. $6.75.

This book is a compilation by the editors of the work of 45 authors. The physical make-up is excellent. The discussions were developed in a series of programs at Iowa State College during the summer of 1952. This series, entitled the "Biostatistics Conference," was sponsored by the College and by the Biometrics Society. The plan, as stated, was to develop discussion on each of many topics by statisticians interested in experimental problems, and by biologists familiar with statistical aids to experimentation.

As such a compilation, the book has not a classic outline except as the plan of discussions provides one. There are five main headings; on general biometric principles, population changes, estimation of populations, determination of biological response, and genetics. Under each heading are various contributions by statisticians and biologists of high standing in the fields covered. Space does not permit listing the names. Among those familiar to entomologists and scientists in associated fields are Snedecor, Sewall Wright, Tukey, Leonard, Thomas Park, Dorn, Hasel, Beall, Bliss, Hopkins, Lush, and others.

Under general principles we see notes on history of biometry, discussions of multivariate analysis and multiple regressions with path coefficients, species classification, growth curves, and experimental designs and philosophy. Under the second heading ecological analyses of species competition are discussed. The part on sampling of populations includes discussion of human populations, forests, wild-life, and distribution problems. The section on biological response takes up dosage-mortality and bioassay problems, tasting tests and feeding experiments, and a discussion of insect resistance to poisons. The genetics section has articles on determination of gene frequencies, genetic effects of radiation, separation of genetic and environmental effects, and genetic structure of populations; it closes with a cytological article.

The articles are of scholarly and broad character, with attention to mathematical and biological principles, and in many cases with numerical examples. The book is concluded by a bibliography of nearly 1,000 titles and an index.

As a reference work, the volume will be a treasure house to biometricians, and to biologists of quantitative interests. It is not a textbook and does not present statistical methods arranged in a definite outline. Much of the material assumes a certain degree of statistical training in the reader. It does not attack many specific entomological problems, but does present much material of importance in their solution. Differentiation of species, population sampling, biological assay, taste tests, resistance to poisons, and genetics (important in developing resistant crop varieties and studying poison resistance) are included.

F. M. WADLEY

Bigger yields with ARAMITE®

UNTREATED KIDNEY BEANS

TREATED WITH ARAMITE

More money for growers!

Aramite, today's safest strongest mite-killer, promises growers bigger, more profitable yields of better fruits, vegetables, row crops, cotton and ornamentals. This is possible because Aramite can effectively control a wide variety of mites at low cost per acre without harming humans, animals or crops. Further advantages of Aramite are ease of use, long residual effect, high compatibility and harmlessness to natural predators.

Naugatuck Chemical

Division of United States Rubber Company
ELM STREET, NAUGATUCK, CONNECTICUT
producers of seed protectants, fungicides, miticides, insecticides, growth retardants, herbicides: Spergon, Phygon, Aramite, Synklor, MH, Atanap.

CLASSIFIED

FOR SALE: Journal of Economic Entomology. Complete sets of Volumes Nos. 7, 8, 9, 10, 17, 20, 21, 43 and 46. Incomplete sets as follows: Vol. 13, No. 1 only; Vol. 20, Nos. 1, 2 and 6; Vol. 22, Nos. 1, 2, 4, 5, 6; Vol. 23, Nos. 1, 2, 3, 4, 6; Vol. 24, Nos. 2, 3, 4, 6; Vol. 44, No. 1 only; Vol. 45, Nos. 1, 2, 5, 6. Complete volumes $3.00 each, not to be broken. Incomplete sets 50¢ each number, plus postage on small orders. Also Index Special Publication No. 7, 1940-1944. T. F. McGehee, Box 472, Gulfport, Mississippi.

POSITION WANTED: Entomologist, Ph.D. 1953, five years research pest control, toxicology and field experience, two years overseas with chemical industry sales promotion, one year in charge vector control, desires teaching or research position. Industrial overseas is acceptable. Write Box W, Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C.

POSITION WANTED by Entomologist, M.S., 34, married, children. Experience includes commercial pest control, insect detection and supervision of control operations, teaching vocational agriculture. Desires Entomology research or experiment work, laboratory and/or field work. Reply to Box V, Entomological Society of America, 1530 P Street, N.W., Washington 5, D.C.

WANTED: JOURNAL OF ECONOMIC ENTOMOLOGY, No. 1 of Vol. 12 (1919). M. A. Yothers, Box 1291, Yakima, Washington.

FOR SALE: Annals of the Ent. Soc. America, complete; Rev. Appl. Ent., Series A, 1927 to date; Index to Econ. Ent., vols. 2-8 and 10; various entomological books. E. J. Newcomer, Box 1291, Yakima, Washington.

INDEX, VOLUME 47, 1954

Ablerus, 39
Abundance, insect, factors, affecting, 398
Acalymma
  trivittata, 194
  vittata, 276, 684, 807
Acanthoscelides obtectus, 923
Acaricides against lone star tick, 76
Acaricides, susceptibility of
  trees to injury by, 738
  various stages of spider mites to, 789
Acemyia
  dentata, 935
  tibialis, 935
Aceria
  lycopersici, 1002
  sheldoni, 356, 520
Acheta assimilis, 926
Achateneura archippivora, 526
Acontia dacia, as a pest of cotton, 1149
Acridomyia canadensis, 935
Acrobasis caryae, 713
Acrosternum hilare, 683
Actia interrupta, 589
Adalia bipunctata, 297
Adelphocoris rapidus, 683
Aedes
  aegypti, 20, 36, 181, 234, 905
  dorsalis, 819
  nigromaculis, 819
  vexans, a migration of, 544
Aedes scutellaris complex
  polynesiensis, 385
  pseudoscutellaris, 385
Agria affinis, 589
Agrotis
  orthogonia, 929
  sp., control of, 362
  ypsilon, 22
Ahasverus advena, 464
Alabama argillacea, 541, 803, 981, 1149
Aldrin, for control of
  alfalfa snout beetle, 637
  apple maggot, 1115
  army cutworm, 1156
  azalea bark scale, 499
  boll weevil, 48, 754, 805, 825
  bollworm, 754, 825
  cabbage maggot, 475
  cattle grubs, 465
  chigger vectors of scrub typhus, 429
  clover root borer, 327
  corn rootworm, 651
  cotton aphid, 754, 805
  cotton flea hopper, 754
  desert damp-wood termite, 366
  Empoasca solana, 534
  fleas, 604
  garden springtail, 174
  grasshoppers in Mexico, 98
  greenhouse whitefly, 531
  house fly, 88, 439
  human bot fly, 540
  lone star tick, 77
  meadow spittlebug, 844
  Melanotus communis, 342
  onion maggot, 495, 852
  onion thrips, 617
  pepper weevil, 1143
  plum curculio, 910, 1115
  potato leafhopper on peanuts, 261
  rice water weevil, 678
  root maggots, 609
  Simulium downsi, 139
  southwestern corn borer, 708
  spider mites, 754, 805
  striped cucumber beetle, 807
  sugarcane beetle, 1155
  Trombicula spp., 430
  western corn rootworm, 693
  wireworms, 864
Aldrin, effect on
  insects when fed to cattle, 35
  phytotoxicity of on trees, 737
  soil flora, 303
  soil treatments on strawberries, 859
  subchronic toxicity of to chicks, 1082
Aldrin, toxicity of, to
  hollyhock weevil, 181
  salt-marsh caterpillar, 649
  tobacco hornworm, 215
Allethrin
  joint action of chlorinated terphenyl, 796
  mixtures, effect of sesamolin, sesamin, and sesamol in, 839
  radioactive, synthesis and chromatographic purification of, 1066
  synergists with, against the body louse, 501
  toxicity of analogs of, to house fly, 664, 888
Allethrin for control of
  cabbage aphid, 993
  cabbage caterpillars, 993
  corn earworm, 364
  house fly in food plants, 88
Allograpta obliqua, 445
Alphitobius diaperinus, 464
Alternaria solani, 899
Altica foliacea, 684
Altitude tolerance of insects, 230
Amblyomma americanum, 13, 76
Amblymerus verditer, 589
Amblypelta, 212
Amphimallon majalis, 618, 811, 1009, 1087
Amphorophora crataegi, 498
Anachaetopsis tortricis, 941
Anagrus, 786
Anastrepha ludens, 891
Anopheles
  crucians, control of, 629
  freeborni, control in rice fields, 818
  quadrimaculatus, 27, 178, 384, 580, 628
Anopheles maculipennis group
  aztecus, 384
  earlei, 384
  freeborni, 384
  occidentalis, 384
  quadrimaculatus, 384
Anthomyia spp., 251
Anthonomus
  eugenii, 188, 1141
  grandis, 48, 177, 543, 753, 803, 824, 928, 981, 1129, 1148
  signatus, control of, 1150
Anuraphis
  bakeri, 717

roseus, 733
Aonidiella
aurantii, 100, 573, 715, 1132
citrina, 1132
Apanteles
fumiferanae, 355, 589
solitaris, 939
Apechthis ontario, 589
Aphelinoidea
anatolica, 786
plutella, 787
Aphids
of the Yakima Valley of Washington, 1117
on potatoes, estimating abundance of, 1024
Aphis
abbreviata, 1025
gossypii, 193, 445, 538, 683, 684, 753, 803, 981, 1149
medicaginis, 903
pomi, 498, 732
spiraecola, dispersion to tropics, 568
Aphytis spp.
maculicornis, 39
near *proclia*, 40
Apion longirostre, life history, control of, 181
Apis mellifera, 316, 765, 965, 969
multiple mating of queens of, 995
Apsylla cistellata, on mango, 563
Apus
biggsi, 820
oryzaphagus, 820
Aramite
effect of in lygus control, 705
phytotoxicity of on trees, 736
Aramite, for control of
apple maggot, 479
boll weevil, 753
bollworm, 753
codling moth, 1094
cotton aphid, 753
cotton flea hopper, 753
desert spider mite, 827, 870
mites, 32, 442
Paratetranychus pratensis, 595
peach silver mite, 867
privet mite, 456
Simulium downsi, 139
spider mites, 753
Tetranychus hicoriae, 714
two-spotted spider mite, 791
Archips rosaceana, 277
Argyrotaenia
citrana, 161
velutinana, 374, 941
Arion ater, control of, 370
Arthropod-borne disease and experimental epidemiology, 420
Aspergillus niger, 369
Aspidiotus
ancylus, sprays for, 624
forbesi, 191
perniciosus, 191, 624
Aspidiotiphagus, near *citrinus*, 40
Athous sp., 597
Attagenus piceus, 1106, 1108
Attractants for
corn earworm, 82
western grape leaf skeletonizer, 58
Autographa
oo, 188
spp., 277
Azotus, 39
Baccha clavata, 445
Bacillus
cereus, 1075
lentimorbus, 1087
popilliae, 1079, 1087
thuringiensis, in relation to European corn borer, 1074
Baits
ammoniacal, 154
for alfalfa snout beetle, 636
for Argentine ant, 591
for European chafer, 620
for hornworm moths, 879
for house fly, 334, 338
metaldehyde, for control of *Arion ater*, 370
for control of tobacco budworm, 173
soymeal-bacterium 14, oriental fruit fly, 157
trap studies with *Drosophila* spp., 935
for vinegar flies, 919
Batocera rufomaculata, 22
Bdellonyssus
bacoti, 1153, 1155
bacoti, altitude tolerance of, 236
bursa, 1153, 1154
sylviarum, 943, 1153, 1155
Benzyl chloride, for control of corn earworm, 364
Berosus pantherinus, 276
BHC as a chemotherapeutic agent, 35
BHC, effect of on
cotton insects, 681
insects when fed to cattle, 35
nitrogen transformations, soil respiration, 303
soil flora, 303
soil treatments on strawberries, 859
BHC, for control of
Acontia dacia, 1150
aphids on hawthorn, 500
Apsylla cistellata, 564
boll weevil, 48, 177, 753, 805, 828, 870, 1130
bollworm, 753, 828, 870, 1131
clover leaf weevil, 928
clover root borer, 327
corn rootworm, 655
cotton aphid, 753, 805
cotton flea hopper, 753
cotton leafworm, 542
Culex tarsalis, 821
flower thrips, 1130
grasshoppers in Mexico, 98
green peach aphid, 781
horn fly, 267
house fly, 88, 439
human bot fly, 540
lesser peach tree borer, 911
meadow spittlebug, 844
onion thrips, 617
peach tree borer, 360, 911
pepper weevil, 1142
periodical cicada, 244
pink bollworm, 177
potato leafhopper on peanuts, 258
root maggots, 609
spider mites, 753, 805
striped cucumber beetle, 807
western corn rootworm, 692
wireworms, 598
Bioclimatic studies of fruit flies, 756
Blatta orientalis, 187
Blattella germanica, 183, 254, 282, 1057
Blissus leucopterus
factors affecting thermal death point of, 882
sorghums resistant to, 536

Bombua
borealis, 673, 848
fervidus, 673, 848
rufocinctus, 673, 848
separatus, 673
ternarius, 674
terricola, 674
vagans, 673
Boopedon nubilum, 936
Borax (saturated), for control of house fly, 439
Bourlietiella hortensis, 173
Bovicola bovis, 701, 1152
Brachyrhinus ligustici, control of, 636
Brevicoryne brassicae, 993
Brevipalpus
inornatus, 449
mites, 356
Bruchus pisorum, 188
Bucculatrix thurberiella, 941, 1149
Bumblebees, domiciles for, 672

C-1100, phytotoxicity of on trees, 737
Cactus, biological control of, 696
Cactoblastis cactorum, 698
Calasoma sp., 270
Calcium arsenate, for control of
Acontia dacia, 1150
boll weevil, 755
bollworm, 755
cotton aphid, 755
cotton flea hopper, 755
cotton leafworm, 542
spider mites, 755
striped cucumber beetle, 807
Calcium carbonate, use as a diluent, 869
Calcium cyanide, for control of rice borer, 186
Calepitrimerus muesebecki, 926
Calobata antennipes, 558
Calomel, for control of onion maggot, 497
Calliphora
spp., 249
terrae-novae, 558
vicina, 558
vomitoria, 558
Callitroga
hominivorax, 35, 188, 465
macellaria, 35, 249, 407, 413
Camnula pellucida, 936
Capitophorus fragaefolii, 945
Capnodis spp.
Carbon monoxide, toxicity to insects, 183
Caritroga macellaria, 558
Carpocapsa pomonella, 23, 161, 188, 189, 276, 402, 732, 768, 936, 1093
Cattle fed insecticides, effect on insects, 35
Cedar chests, effects of, on insects, 1107
Centrodora n. sp., 845
Ceracia dentata, 935
Ceraphron n. sp., on clover seed midge, 146
Ceratitis capitata, 20, 23, 153, 507, 756
Ceratomegilla fuscilabris, 296
Ceratophyllus gallinae, 943
Ceratostomella ulmi, 739
Cercospora leafspot, 257
Ceresan M, in seed-corn maggot control, 1041
Chelinidea
tabulata, 697
vittiger, 697
Chaetocnema pulicaria, 683
Chilocorus
bipustulatus, 40
stigma, 40
Chirothrips mexicanus, effect on grass-seed, 709
Choristoneura pinus, parasites of, 588
Chlordane, effect on
cotton insects, 681
insects when fed to cattle, 35
soil flora, 303
soil treatments on strawberries, 859
Chlordane, for control of
alfalfa snout beetle, 637
apple maggot, 1115
Argentine ant, 591
azalea bark scale, 499
cabbage aphid, 993
cabbage caterpillars, 993
cabbage maggot, 475
cattle lice, 701
clover root borer, 327
corn rootworm, 651
desert damp-wood termite, 366
Empoasca solana, 534
garden springtail, 174
grasshoppers in Mexico, 98
green peach aphid, 781
greenhouse whitefly, 531
house fly, 88, 439
Japanese beetle, 165
lice on cattle, 1152
lone star tick, 77
Maruca testulalis, 533
Melanotus communis, 342
mites, laboratory, 443
onion maggot, 495, 852
pepper weevil, 1142
plum curculio, 1115
potato leafhopper on peanuts, 258
rice water weevil, 678
root maggots, 609
Simulium downsi, 139
strawberry weevil, 1150
striped cucumber beetle, 807
Trombicula spp., 430
western corn rootworm, 693
Chlordane
persistence of in soils, 165
phytotoxicity of on trees, 737
Chlordane, toxicity of, to
hollyhock weevil, 181
native elm bark beetle, 745
smaller European elm bark beetle, 745
Chlorobenzilate, for control of
codling moth, 1094
house fly, 439
mites, 32
Paratetranychus pratensis, 595
peach silver mite, 867
privet mite, 456
various stages of two spotted spider mite, 791
Chlorobenzilate, phytotoxicity of on trees, 736
Choristoneura fumiferana, 355, 402, 589
Chlorochroa
ligata, 377
sayi, 377
Chlorthion, for control of
Anopheles crucians, 629
boll weevil, 755, 805
bollworm, 755
cattle grubs, 466
codling moth, 1094
common malarial mosquito, 629
corn earworm on peanuts, 1112
cotton aphid, 755, 805
cotton leafworm, 542

desert spider mite, 870
fall armyworm on peanuts, 1112
granary weevil, 705
house fly, 702, 1140
lesser grain borer, 705
rice weevil, 705
spider mites, 755, 805
yellow clover aphid, 1157
Chlorthion, toxicity to little house fly, 1140
Chorizagrotis auxiliaris, control of, 1156
Chromaphis juglandicola, 192, 366
Chromatography
of gyptol and gyptyl ester, 321
paper, technique in connection with, 934
Chrysomphalus aonidum, 20, 23
Chrysopa, immunity to Systox,
oculata, 448
rufilabris, 448
Chrysops discalis, insecticide toxicity to, 361
Cimex lectularius, 183, 1057
Cimexopsis, 1144
Cirphis unipuncta, 277
Circulifera tenellus 44, 122, 214, 785
Citellus beecheyi beecheyi, 1070
Closterocerus sp., 942
Coccinella novemnotata, 297
Coccobacillus acridiorum, 1080
Coccus
hesperidum, 718, 1131
pseudomagnoliarum, 1132
Coleomegilla maculata, 445, 683
Collops spp. 683
Compound A42, for house flies, 979
Compound G22008, hazards of residues, 1056
Compound G-23611, for control of
aphids on hawthorn, 500
tobacco flea beetle, 347
Compound K-6451, residues of, 1027
Compound L 13/59, for control of
cattle grubs, 466, 713
house fly, 336, 439, 703, 980
Compound OS-1836, for control of
boll weevil, 870
cotton leafworm, 870
Compound OS-2046, for control of
boll weevil, 870
cotton leafworm, 870
Compound 876, for control of
codling moth, 774
peach silver mite, 867
two-spotted spider mite, 791
Compound 923, for control of
mites, 32, 595, 791
Simulium downsi, 139
Compound 923 phytotoxicity of on trees, 736
Compound 1189 for control of
apple maggot, 479
European red mite, 732
Compound 21/116, for control of
codling moth, 1094
corn earworm on peanuts, 1112
fall armyworm on peanuts, 1112
Compound 21/199, for control of
cattle grubs, 466, 713
house fly, 702, 980
Compound 21/199, with pyrethrum synergists, 73
Compound 21/200, with pyrethrum synergists, 73
Conoderus lividus, 863
Conotrachelus nenuphar, 191, 355, 731, 871, 909, 1115
Copper sulphate, for control of house fly, 439
Corn planting dates and Japanese beetle, 349
Cryolite, for control of
Acontia dacia, 1150
Empoasca solana, 534
house fly, 439
Maruca testulalis, 533
pepper weevil, 1142
western grape leaf skeletonizer, 54
CS-589, for control of codling moth, 771
CS-645A, for control of
codling moth, 1094
meadow spittlebug, 844
Simulium downsi, 139
striped cucumber beetle, 807
CS-674A, for control of
beet leafhopper, 123
codling moth, 1094
meadow spittlebug, 844
Simulium downsi, 139
CS-708, for control of
apple maggot, 479, 732
beet leafhopper, 123
black bean aphid, 601
codling moth, 732, 770, 1094
corn earworm, 603
Empoasca solana, 534
European apple sawfly, 733
greenhouse whitefly, 533
horn fly, 267
house fly, 439, 979, 999
Maruca testulalis, 533
meadow spittlebug, 844
Mexican bean beetle, 601
onion thrips, 617
pea aphid, 716
periodical cicada, 244, 459
plum curculio, 731, 910
potato leafhopper on beans, 601
rosy apple aphid, 733
Simulium downsi, 139
striped cucumber beetle, 708
tobacco budworm, 173
tobacco flea beetle, 346
two-spotted spider mite, 601
CS-708, toxicity of, to tobacco hornworm, 215
CS-728, for control of
codling moth, 770, 1094
meadow spittlebug, 844
plum curculio, 910
Cucumbers, tolerance of, to technical DDT, 272
Culex
pilosus in Texas, 63
pipiens, 27
quinquefasciatus, 235, 903
tarsalis, 819
Culex pipiens complex
molestus, 384
pipiens pallens, 384
quinquefasciatus (=*fatigans*) 384
Cunilate, toxicity of, to honey bees, 970
Cuterebra lepivora, from rabbit, 1146
Cybocephalus sp., 40
Cycloneda sanguinea, 297, 445, 683
Cylas formicarius elegantulus, 703
Cynaeus angustus, 464
Cynomyopsis cadaverina, 249, 558
Cyperus rotundus, response to insecticides, 435
Cytochrome oxidase, insecticide effect on, 723
Cytorhinus
fulvus, 786
mundulus, 786

Dacus
cucuminatus, 154
cucurbitae, 153, 226, 507, 704, 756
dorsalis, 153, 507, 756

dorsalis, screening tests of fumigants for, 549
oleae, 21, 23
Dactylopius opuntiae, 697
Darco S51, in tests against codling moth, 1094
Dasyneura
gentneri, life history of, 141
leguminicola, 141
D-D, effect on soil flora, 304
D-D mixture, soil fumigation with, 1101
DDD (see TDE)
DDT, accumulation in soils, 467
DDT, for control of
Acontia dacia, 1150
Aedes dorsalis, 820
Aedes nigromaculis, 820
Angoumois grain moth, 1125
Anopheles crucians, 629
Anopheles freeborni, 821
apple maggot, 479, 732
Apsylla cistellata, 564
beet leafhopper, 123
boll weevil, 48, 177, 753, 754, 805, 825, 870, 1130
bollworm, 753, 825, 828, 870, 1131
brown-tail moth, 171
cabbage aphid, 993
cabbage caterpillars, 993
cabbage looper, 564, 937
clover leaf weevil, 927
codling moth, 161, 732, 768, 936, 1093
common malarial mosquito, 629
corn earworm, 603, 1124
cotton aphid, 753, 805
cotton flea hopper, 753
cotton leafworm, 542
cotton leaf perforator, 942
cranberry fruitworm, 519
Culex tarsalis, 821
elm leaf beetle, 744
Empoasca solana, 534
Erythroneura lawsoniana, 361
European apple sawfly, 733
European hen flea, 942
European pine shoot moth, 301
fleas, 604
flower thrips, 1130
garden springtail, 174
grasshoppers in Mexico, 99
greenhouse whitefly, 531
green peach aphid, 781
horn fly, 266
house fly, 88, 439, 978, 1140
human bot fly, 540
imported cabbageworm, 564
lesser peach tree borer, 911
lice on cattle, 1152
lone star tick, 77
Maruca testulalis, 533
meadow spittlebug, 844
Melanotus communis, 342
native elm bark beetle, 739
onion maggot, 495
onion thrips, 617
orange tortrix, 163
oriental fruit moth, 147
peach tree borers, 359, 911
pecan nut casebearer, 714
pepper weevil, 1141
periodical cicada, 458
pink bollworm, 177
plum curculio, 731, 909
potato flea beetle, 190
potato leafhopper on peanuts, 258
Putnam scale, 624
red-headed pine sawfly, 265
rhododendron lace bug, 264
rice water weevil, 678
rice weevil, 1125
strawberry weevil, 1150
root maggots, 612
rosy apple aphid, 733
Simulium downsi, 139
smaller European elm bark beetle, 624, 739
spider mites, 753, 805
striped cucumber beetle, 807
sweetclover weevil, 117
tobacco budworm, 172
tobacco flea beetle, 346
tobacco thrips on peanuts, 259, 1112
vinegar flies, 921
western corn rootworm, 359
western grape leaf skeletonizer, 54
willow flea weevil, 264
yellow clover aphid, 1157
DDT, effect of on
cotton insects, 681
cytochrome oxidase, 723
house fly larvae, 633
nitrogen transformations, soil respiration, 307
soil flora, 303
Tuberculatus ulmifolii, 658
two-spotted spider mite on elm, 658
DDT
factors affecting rate of penetration, 798
phytotoxicity of on trees, 737
resistant strain of *Drosophila*, 393
DDT, toxicity of, to
hollyhock weevil, 181
little house fly, 1140
native elm bark beetle, 745
smaller European elm bark beetle, 745
tobacco hornworm, 215
Demeton (Systox), effect of on
cotton aphid, 684
cotton aphid predators, 445
various stages of two-spotted spider mite, 791
Demeton (Systox) for control of
codling moth, 772, 1096
corn earworm on peanuts, 1112
Empoasca solana, 534
fall armyworm on peanuts, 1112
meadow spittlebug, 844
Melanotus communis, 343
mites, 32, 520, 595, 867, 870, 945, 1021
olive scale, 290
pea aphid, 491, 716
periodical cicada, 459
potato leafhopper, 711
southern corn rootworm, 711
strawberry aphid, 945
tobacco flea beetle, 346
tobacco thrips, 711, 1112
western flower thrips, 945
Dermanyssus gallinae, 1153, 1155
Dermatobia hominis, control of, 540
Desima funeralis, 276
DFDT, for control of striped cucumber beetle, 807
Diabrotica
grandiosella, 707
longicornis, 651
undecimpunctata, 194, 276, 683, 711, 807
virgifera, 358, 691
Dialeurodes citri, 7
Diamanus montanus, 605, 1074
Diaspidiotus sp., 39
Diaphania hyalinata, 188
Diazinon, effect

in house fly baits, 336
on stages of two-spotted spider mite, 791
with pyrethrum synergists, 73
Diazinon, for control of
Anopheles crucians, 629
apple maggot, 479
cabbage looper, 937
cattle grubs, 466
codling moth, 770, 1094
common cattle grub, 713
common malarial mosquito, 629
corn earworm, 364
house fly, 369, 439, 632, 702, 979, 1140
pea aphid, 716
privet mite, 456
yellow clover aphid, 1157
Diazinon, toxicity of, to
deer fly, 361
little house fly, 1140
Dichloro-propane-dichloropropene mixtures, 1101
Dieldrin, colorimetric detection of, 185
Dieldrin, effect of on,
insects when fed to cattle, 35
soil flora, 303
soil treatments on strawberries, 859
parasites of salt-marsh caterpillar, 528
Dieldrin, for control of,
alfalfa snout beetle, 637
alfalfa weevil, 314
apple maggot, 479, 1115
Argentine ant, 591
army cutworm, 1156
azalea bark scale, 499
boll weevil, 48, 177, 647, 754, 805, 825, 870
bollworm, 754, 825, 870
cabbage aphid, 993
cabbage caterpillars, 993
cabbage maggot, 475
cattle grubs, 465
chigger vectors of scrub typhus, 429
clover root borer, 327
common cattle grub, 713
cotton aphid, 754, 805
cotton flea hopper, 754
Empoasca solana, 534
fleas, 604
grasshoppers in Mexico, 98
greenhouse whitefly, 531
horn fly, 267
house fly, 88, 439
lone star tick, 77
meadow spittlebug, 314, 844
Melanotus communis, 343
onion maggot, 495, 852
onion thrips, 617
Paratetranychus pratensis, 595
peach tree borer, 360
pecan nut casebearer, 714
periodical cicada, 244
plum curculio, 1115
potato flea beetle, 190
potato leafhopper on peanuts, 261
rice water weevil, 678
root maggots, 609
seed-corn maggot, 1041
Simulium downsi, 139
southwestern corn borer, 708
spider mites, 754, 805
spiny bollworm, 368
striped cucumber beetle, 708
tobacco flea beetle, 346
sugarcane beetle, 1155
Trombicula spp., 430
vinegar flies, 921
wireworms, 864
Dieldrin toxicity of, to
hollyhock weevil, 181
little house fly, 1140
native elm bark beetle, 745
salt-marsh caterpillar, 649
smaller European elm bark beetle, 745
tobacco hornworm, 215
Dieldrin
phytotoxicity of on trees, 737
subchronic toxicity of to chicks, 1082
Dikrella cockerellii, 238
Diluents for toxaphene, 52
Dispersal, fly, 405, 413, 830
Ditolyl trichloroethane, for house fly, 88
Ditolyltrichloroethane, control tests, western grape leaf skeletonizer, 56
DMC, effect on
phytotoxicity on trees, 736
various stages of two-spotted spider mite, 791
DMC, for control of
codling moth, 774, 936
mites, 32, 456, 595, 867
DN-289, against two-spotted spider mite, 791
DN-289, for control of mites, 32, 868
DN-111, against two-spotted spider mite, 791
Domiciles, bumblebee, temperature studies in, 847
Drosophila
analysis of a DDT-resistant strain, 393
for microbioassay of insecticide residues, 180
affinis, 935
algonquin, 935
funebris, 935
hydei, 935
melanogaster, 180, 917, 935
sp., 20, 377
repleta, 935
transversa, 935
Drosophila melanogaster
genetics of resistance to DDT in, 387
resistance of to insecticides, 583
Dutch elm disease, control of, 739
Dysmicoccus brevipes, 213

Earias insulana, 22, 23, 367, 708
Echidnophaga gallinacea, 605, 1070
Ecology, insect, microenvironment in, 205
Eleodes sp., 597
Empoasca
abrupta, 194, 683
fabae, 257, 683, 711, 899
solana, 213, 530, 534
Endrin, for control of
Acontia dacia, 1150
alfalfa snout beetle, 638
alfalfa weevil, 314
army cutworm, 1156
boll weevil, 647, 755, 805, 827
bollworm, 755, 827
codling moth, 1097
clover leaf weevil, 927
clover root borer, 329
codling moth, 771
corn earworm, 97
corn rootworm, 651
cotton aphid, 755, 805
cotton flea hopper, 755
cotton leaf perforator, 942
cotton leafworm, 542
cranberry fruitworm, 519
Empoasca solana, 534
grasshoppers in Mexico, 98

Japanese beetle, 707
meadow spittlebug, 314
Melanotus communis, 343
plum curculio, 910
southwestern corn borer, 708
spider mites, 755, 805
spiny bollworm, 368
tobacco flea beetle, 346
Endrin
phytotoxicity of on trees, 737
subchronic toxicity of to chicks, 1082
Endrin, toxicity of, to
salt-marsh caterpillar, 649
tobacco hornworm, 215
Entomology
responsibility to human welfare, 1
systematic—retrospect and prospect, 1159
Ephestia kühniella, 282
Epicauta spp., 188
Epilachna varivestis, 8, 188
Epitrix
cucumeris, 190, 896
hirtipennis, 346
EPN
against two-spotted spider mite, 791
effect of on soil flora, 303
EPN, for control of
Anopheles crucians, 629
apple maggot, 1115
black pecan aphid, 931
boll weevil, 177, 805, 828
bollworm, 828
codling moth, 770, 1094
common cattle grub, 713
common malarial mosquito, 629
cotton aphid, 805
cotton leafworm, 542, 807
cranberry fruitworm, 519
deer fly, 361
Empoasca solana, 534
greenhouse whitefly, 531
hickory shuckworm, 931
house flies, 979
olive scale, 290
onion thrips, 617
oriental fruit moth, 148
Paratetranychus pratensis, 595
peach tree borer, 360
pecan nut casebearer, 714
periodical cicada, 244
pink bollworm, 177
plum curculio, 909, 1115
Simulium downsi, 139
southwestern corn borer, 708
spider mites, 805, 931
striped cucumber beetle, 807
Equipment for
altitude tolerance studies, 230
determining pyrethrum repellency on grain, 1104
evaluating mite populations on wheat, 594
evaluating pesticide dusts, honey bees, 965
fog generator, portable, 171
house fly studies, 130
mixing economic poisons, 353
oriental fruit fly bait studies, 153
sampling range vegetation, 1133
screening chemicals for black flies, 135
sifting soil for subterranean insects, 1006
trapping European chafer, 618
trapping hornworm moths, 879
trapping insects in flight, 944
Eriococcus azaleae, 498
Eriophyes pyri, summer control of, 1020
Eriosoma lanigerum, 733
Eriophyidae, 744
Erythroneura
elegantula, 238
lawsoniana, 361
variabilis, 238
Estigmene acrea, 188, 525, 1149
Ethyl parathion, for control of
green peach aphid, 781
turnip aphid, 782
Ethylene dibromide, for control of
Mexican fruit fly, 891
peach tree borer, 911
Euetheola rugiceps, control of, 1155
Eurytoma curta, 402
Euscepes postifasciatus, 703
Euschistus
euschistoides, 380
serous, 379, 683
variolaris, 379
Euschöngastia, 434
Euxesta notata, 558
Evergestis rimosalis, 188
Exochus sp., 589
Exorista larvarum, 526

Fannia
canicularis, 558, 1137
manicata, 558
pusio, 410
spp., 251
Feltia subgothica, 277
Fenusa pusilla, 498
Ferbam, for control of
apple maggot, 732
European red mite, 732
periodical cicada, 458
Flavor
effect of sprays on apples, 734
evaluation of treated strawberries, 862
Fleas, control of on ground squirrels, 604
Flower bugs, effect of insecticides on, 543
Folic acid antagonist, effect on house fly, 932
Formaldehyde, for control of corn earworm, 364
Formalin, for control of house fly, 439
Frankliniella
fusca, 257, 711, 1111
moultoni, 945
tritici, 257, 1129, 1149
Fruit flies, bioclimatic studies of, 756
Fumigants
for stored-product insects, 923
screening tests of, for oriental fruit fly, 549
soil, in pineapple land, 1101
Fungicides, effect of on plant emergence, 1040

Gahrliepia, 434
Galerucella xanthomelana, 276, 744
Galls on mango by *Apsylla*, 563
Gastrophysa cyanea, 188
Genetics in entomology, 377
Geocoris
punctipes, 683
spp., 193, 543
Glyphonyx recticollis, 863
Glypta fumiferanae, 355, 589
Gnorimoschema operculella, 147, 278
Grapholitha molesta, 147, 278, 355
Gryllotalpa gryllotalpa, 22
Gymnocarcelia sp., 526
Gyptol, chromatography of, 321
Gyptyl ester, chromatography of, 321

Habrocytus sp., 589
Habrolepis sp., 39
Haematosiphon inodorus, 224, 1144
Haplothrips faurei, 403
Harogenes molestae, propagation of, 278
Harrisina brillians, 54, 58
Heliothis
armigera, 82, 94, 188, 364, 538, 753, 824, 827, 981, 1112, 1124, 1129, 1149, 1158
virescens, 172
Helopeltis, 212, 213
Hemithrixion oestriforme, 935
Hendecenoic (undecylenic) acid, 13, 19
Heptachlor, for control of
alfalfa snout beetle, 638
alfalfa weevil, 314
apple maggot, 479
Argentine ant, 591
army cutworm, 1156
boll weevil, 754, 805
bollworm, 754
cabbage caterpillars, 994
cabbage maggot, 475
corn rootworm, 651
cotton aphid, 754, 805
cotton flea hopper, 754
Empoasca solana, 534
fleas, 604
greenhouse whitefly, 531
horn fly, 267
house fly, 439, 978
meadow spittlebug, 314, 844
Melanotus communis, 342
onion maggot, 495, 852
onion thrips, 617
pepper weevil, 1143
plum curculio, 910, 1116
potato flea beetle, 190
rice water weevil, 678
root maggots, 609
Simulium downsi, 139
spider mites, 754, 805
striped cucumber beetle, 807
sugarcane beetle, 1155
western corn rootworm, 693
wireworms, 864
Heptachlor, phytotoxicity of on trees, 737
Heptachlor, toxicity of, to
hollyhock weevil, 181
tobacco hornworm, 216
Herbicides, 2,4-D on experimental lemons, 715
Herpetomonas muscae domesticae, 233
Hesperocimex, 1144
Hippodamia
convergens, 297, 445, 683
parenthesis, 298
tredecim-punctata, 277
Hoplocampa testudinea, 733
Hoplodictypa sp., 558
Hoplopsyllus anomalus, 605, 1074
Hybridization
among mosquitoes, insecticide resistance, 383
interspecific, among insects, 377
pesticide resistance, 377
Hydnocera pubescens, 683
Hydrotaea sp., 558
Hydrous triangularis, 820
Hylastinus obscurus, control of, 327
Hylemya
antiqua, 494, 852
brassica, 475, 607
cilicrura, 105, 558, 607, 1040
floralis, 607
lupini, life history in Florida, 103
sp., 558
Hylotrupes bajulus, in Mass., 362
Hylurgopinus rufipes, 739
Hymenia recurvalis, 188
Hypera
postica, control of, 313
punctata, 926
Hyperaspis
fimbriolatus, 683
undulata, 683
Hypoderma lineatum, 35, 712
Hypoderma, use of phosphorus compounds against
bovis, 465
lineatum, 465

Ichneumon neutralis, 526
Indalone, 13, 19
Insecticides
against cotton pests, 803, 869
deposits for elm bark beetles, 739
fed cattle, effect on insects, 35
field evaluation of against codling moth, 1094
impregnated cords against house flies, 975
mosquitoes resistant to, 386
phytotoxicity of, 735
relation of to insects in cotton fields, 681
residual, for insects in food plants, 87
response of nut grass to, 435
resistance of house fly to, 984, 990
soil applications to kill plum curculio, 1115
trees susceptible to injury by, 738
wettable powder or emulsions compared with mineral seal oil on calves, 1144
Insecticides, effect of
soil treatments on strawberries, 859
systemic, on peanut insects and peanuts, 1111
weather on toxicity, 646
Insecticides, effect of, on
bacteria, *Streptomyces*, and molds in soil, 302
beneficial insects, 316, 403, 528, 543, 716, 969
cholinesterase systems of fruit flies, 507
muskmelons, 808
unhatched larvae of pale western cutworm, 929
plant emergence, 1040
Insects
altitude tolerance of, normal and infected, 230
and plant disease, 210
associated with salt cedar, 1126
control of on cotton, 753, 1129
control of in stored grain, 705
ecology, microenvironment in, 205
eradication procedures, 6
flight, control in food processing plants, 87
lipids and insecticidal action, 578
pests in Israel, 19
pests of ornamentals, control of, 498
resistance of crop plants to, 1036
resistance to insecticides, variation in, 586
response of to black and white light, 275
stored-grain, in teosinte, 630
stored-product, and packaging films, 282
Isodrin, for control of
alfalfa snout beetle, 638
boll weevil, 805
cabbage caterpillars, 994
clover leaf weevil, 927
clover root borer, 329
codling moth, 771, 1097
corn earworm, 97
corn rootworm, 651
cotton aphid, 805
cotton leafworm, 542

Empoasca solana, 534
grasshoppers in Mexico, 98
Japanese beetle, 707
spider mites, 805
tobacco flea beetle, 346
Isodrin
phytotoxicity of on trees, 737
subchronic toxicity of to chicks, 1082
Isodrin, toxicity of, to tobacco hornworm, 216
Isolan, for control of codling moth, 1094
Israeli agriculture, 19
Itoplectis conquisitor, 589
Iphidulus, 660
Iridomyrmex humilis, control of, 591

Kalotermes (*Paraneotermes*) *simplicicornis*, control, 365
Karathane, against two-spotted spider mite, 791

Laboratory, research, dedication of, 371
Laelaptidae, predators of spider mites, 176
Laemophloeus
pusillus, 464
sp., 630
Lagocheirus funestus, 699
Lanchaea sp., 558
Laphygma frugiperda, 538, 1112
Lasioderma serricorne, 1106
Laspeyresia
caryana, 931
prunivorella, 277
Latrodectus mactans, 682
Lead arsenate, effect of soil treatments on strawberries, 859
Lead arsenate, for control of
apple maggot, 479, 732
codling moth, 161, 771, 1095
European apple sawfly, 733
European red mite, 732
orange tortrix, 164
plum curculio, 731, 871, 909
rosy apple aphid, 733
Lecanium pruinosum, 192
Lederplex, 155
Legume seed crops, *Tetranychus* spp. control, 30
Lepidosaphes ulmi, 402, 498
Leptothrips mali, 1003
Lethane 384, control of house fly, 439
Light, black and white, response of insects to, 275
Lime, for control of periodical cicada, 458
Limonius
californicus, 188
canus, 188
sp., 597
Lindane, effect of on
calves, 1145
deer fly, 361
hollyhock weevil, 181
insects when fed to cattle, 35
little house fly, 1140
native elm bark beetle, 745
smaller European elm bark beetle, 745
tobacco hornworm, 216
soil treatments on strawberries, 862
Lindane, for control of
apple maggot, 1115
azalea bark scale, 499
cabbage aphid, 993
cabbage caterpillars, 993
cattle grubs, 465
clover leaf weevil, 927
clover root borer, 327
cranberry fruitworm, 519
Culex tarsalis, 821
greenhouse whitefly, 532
green peach aphid, 781
house fly, 439, 1140
lone star tick, 77
Maruca testulalis, 533
meadow spittlebug, 844
Melanotus communis, 342
mites, laboratory, 443
pepper weevil, 1142
plum curculio, 1115
rhododendron lace bug, 264
rice water weevil, 678
root maggots, 612
seed-corn maggot, 1041
Simulium downsi, 139
southwestern corn borer, 708
striped cucumber beetle, 708
Trombicula spp., 430
turnip aphid, 782
western corn rootworm, 693
wireworms, 864
yellow clover aphid, 1157
Lindane
phytotoxicity of on trees, 737
resistance to, by German cockroach, 254
resistance to, by house fly, 130, 990
Linognathus vituli, 701, 1152
Lipids of insects and insecticidal action, 578
Liriomyza
langei, injury to pepper plants by, 357
pusilla, 538
spp., 357
Lissorhoptrus simplex, control of, 676
Lixus juncii, 21, 23
Lophocateres pusillus, 1106
Lophophora, 378
Loro, for control of azalea bark scale, 499
Lucilia illustris, 249, 558
Lygus
desertus, resistance to DDT, 704
elisus, resistance to DDT, 704
hesperus, resistance to DDT, 704
lineolaris, 683
sp., 192
Lymaenon, 786
Lypha setifacies, 589

Macrocentrus ancylivorus, 147, 278
Macrosiphum
pisi, 113, 188, 490, 716, 1122
solanifolii, 1025, 1117, 1122
Magicicada septendecim in
Maryland, 242
Pennsylvania, 457
Malacosoma
americana, 276
disstria, 269
fragilis, 268, 269
pluviale, 269
Malathion, for control of
Acontia dacia, 1150
Anopheles crucians, 629
aphids on hawthorn, 500
apple maggot, 479
azalea bark scale, 499
birch leaf miner, 499
black bean aphid, 601
boll weevil, 754
bollworm, 754
boxwood leaf miner, 499
cabbage looper, 937
codling moth, 770, 936, 1096

common cattle grub, 713
common malarial mosquito, 629
cotton aphid, 754
cotton flea hopper, 754
cranberry fruitwork, 519
desert spider mite, 870
Empoasca solana, 534
garden springtail, 174
granary weevil, 705
house fly, 369, 439, 703, 979, 999, 1140
lesser grain borer, 705
Maruca testulalis, 533
Mexican bean beetle, 601
northern fowl mite, 943
olive scale, 290
onion thrips, 617
orange tortrix, 164
oystershell scale, 498
Paratetranychus pratensis, 595
pea aphid, 716
pepper weevil, 1143
periodical cicada, 244, 459
pine needle scale, 499
potato leafhopper on beans, 601
Putnam scale, 624
red-headed pine sawfly, 265
rice weevil, 705
Simulium downsi, 139
soft scale, 1132
spider mites, 456, 754, 867
tomato russet mite, 1005
two-spotted spider mite, 601, 791
vinegar flies, 921
yellow clover aphid, 1157
Malathion
phytotoxicity of on trees, 736
tests with pyrethrum synergists, 73
Malathion, toxicity of, to
deer fly, 361
little house fly, 1140
tobacco hornworm, 216
Maruca testulalis, control of, 530
Mediolata sp., 926
Melanocallis caryaefoliae, 931
Melanophthalma distinguenda, 683
Melanoplus
bivitattus, 936
bruneri, 936
confusus, 936
mexicanus, 485, 936
packardii, 936
Melanotus communis, 341, 863
Meligethes seminulum, biology of, 127
Melipona, sp., 320
Melitaria
doddalis, 698
prodenialis, 698
Meloidogyne
hapla, 711
sp., 362
Metaldehyde, for control of
Arion ater, 370
Metasyrphus wiedemanni, 445
Metacide, for control of
boll weevil, 753
bollworm, 753
cabbage looper, 937
codling moth, 770, 1094
cotton aphid, 753
cotton flea hopper, 753
cotton leafworm, 542
desert spider, mite, 870
Empoasca solana, 534
house fly, 439
mites, 32, 595
olive scale, 290
onion thrips, 617
oriental fruit moth, 148
periodical cicada, 244
Simulium downsi, 139
spider mites, 753
striped cucumber beetle, 807
Metatetranychus
citri, 356, 520, 904, 1027
ulmi, 402, 460, 731
Metaphycus leuteolus, 1131
Methods for
application of unknown materials in paper chromatography, 934
appraising root maggot damage, 610
artificial insemination of queen bees, 765
bioclimatic studies of fruit flies, 757
control of cattle lice, 701, 1152
determining dieldrin residues in oranges, 1034
determining distribution of radioactive phosphorus in house flies, 973
determining number of queen bee matings, 996
determining residues of K-6451, 1028
estimating aphids on potatoes, 1024
evaluating injury to potato leaves by leafhoppers, flea beetles, and early blight, 894
evaluation of sprays against cockroaches, 23
house fly studies, 130, 369, 938, 975
oriental fruit fly bait studies, 153
rearing little house fly, 1137
rearing soft scale, 718
rearing stable flies, 940
sampling for European chafer, 811, 1009
sampling range vegetation, 1133
screening chemicals for larval control of blackflies, 135
spraying cockroaches, 23
studying Triatominae, 170
testing with mites, 594, 790, 1084, 1153, 1154
ventilating small cage battery, 126
Methoxychlor, effect on
calves, 1144
little house fly, 1140
native elm bark beetle, 745
smaller European elm bark beetle, 745
trees, 737
Methoxychlor, for control of
alfalfa weevil, 314
apple maggot, 479, 732
beet leafhopper, 123
cabbage aphid, 993
cabbage caterpillers, 993
cherry fruit fly, 746
clover leaf weevil, 927
clover root borer, 328
codling moth, 162, 732, 771, 936, 1096
cranberry fruitworm, 519
Empoasca solana, 534
European apply sawfly, 733
European red mite, 732
garden springtail, 174
greenhouse whitefly, 531
horn fly, 267
house fly, 88, 439, 1140
lice on cattle, 1152
Maruca testulalis, 533
meadow spittlebug, 314, 844
orange tortrix, 163
pecan nut casebearer, 714
periodical cicada, 244, 459
plum curculio, 731, 910

potato leafhopper on peanuts, 261
red-headed pine sawfly, 265
rhododendron lace bug, 264
rosy apple aphid, 733
Simulium downsi, 139
striped cucumber beetle, 807
tobacco budworm, 173
turnip aphid, 782
western grape leaf skeletonizer, 56
willow flea weevil, 264
Methyl parathion, for control of
Anopheles crucians, 629
boll weevil, 754, 805
bollworm, 754
common malarial mosquito, 629
cotton aphid, 754, 805
cotton flea hopper, 754
desert spider mite, 870
green peach aphid, 781
mites, 32, 595
onion thrips, 617
Simulium downsi, 139
south western corn borer, 708
spider mites, 754, 805
tobacco budworm, 173
turnip aphid, 782
yellow clover aphid, 1157
Miccotrogus picirostris, 944
Micracis hirtellus, damage to telephone cables, 933
Mineola vaccinii, control of, 518
Mites, control of
in clothes moth cultures, 93
on cotton, 753
on laboratory mice, 442
Mites, feeding on heparinized blood, 1154
Mold control in fly rearing media, 367
Monarthropalpus buxi, 498
Moneilema armata, 699
Mosquitoes, problems in speciation, 383
Musca domestica, 27, 35, 73, 87, 188, 338, 369, 558, 632, 701, 796, 830, 839, 889, 932, 938, 1137
Musca domestica
altitude tolerance of, 233
adsorption, distribution of DDT in, 1058
bait studies, 335, 438
control of, by sanitation, 194
control of in dairies, 999
dispersal, 405, 413
factors influencing efficency of insecticide cords against, 975
in microbioassay of insecticide residues, 181
mold control in rearing media, 367
production sources, 245
resistance to insecticides, 72, 129, 973, 1058
toxicity of allethrin analogs to, 664
Muscina
assimilis, 558
spp., 249
stabulans, 418, 558
Myobia musculinus, control of, 442
Myocoptes musculinus, control of, 442
Myospila medatabunda, 558
Myzocallis ulmifolii, 744
Myzus
persicae, 538, 570, 749, 775, 780, 1025, 1117
solani, 1025

Nabis ferus, 193
Neoclytus
acuminatus, 1150
acuminatus hesperus, 1150
Neodiprion lecontei, control of, 263
Neotran
against two-spotted spider mite, 791
for control of mites, laboratory, 442
Nezara viridula, 683
Nicotine sulfate, for control of
azalea bark scale, 499
codling moth, 772
green peach aphid, 781
house flies, 979
meadow spittlebug, 844
northern fowl mite, 943
potato leafhopper on peanuts, 259
tobacco thrips on peanuts, 259
turnip aphid, 782
walnut aphid, 367
Nicotine, synergism with pyrethrum, 219
Nilotalspis halli, 7, 39
Nitrox, for control of codling moth, 1094
Noctua c-nigrum, 277
Nomia melanderi, 30, 539, 717
NPD, for control of
Anopheles crucians, 629
codling moth, 1094
clover root borer, 329
common malarial mosquito, 629
Empoasca solana, 534
house fly, 439, 979, 999
Putnam scale, 624
Nuchar, in tests against codling moth, 1094
Nygmia phaeorrhoea, control of, 171

Octamethylpyrophosphoramide (see schradan)
Oil, with parathion for California red scale, 100
Oils, petroleum, effect of narrow-cut fractions of different composition on citrus, 107
Oligosita, 786
Olla abdominalis, 683
Oncopeltis fasciatus, 188, 219
Ophyra
leucostoma, 255, 418, 558
spp., 249
Orientus ishidae, 733
Orius insidiosus, 296, 683
Ornamentals, control of insect pests of, 498
Oryzaephilus surinamensis, 282, 464, 583, 630, 923, 1106
Ovotran, for control of
codling moth, 1094
corn earworm, 364
mites, 30, 93, 442, 456, 595, 791, 1027

Pachybrachis
diversus, 684
immaculatus, 684
Packaging films for stored-product insects, 282
Paradichlorobenzene, for control of
corn earworm, 364
peach tree borers, 359
Paragordius varius, 926
Para-oxon, for control of
Anopheles crucians, 629
common malarial mosquito, 629
Parasites
dipterous, of grasshoppers, 935
egg, introduction of for beet leafhopper, 785
for control of oriental fruit moth, 147
of jack-pine budworm, 588
Paratetranychus
citri, control with oil-parathion, 102
coiti, 356
pratensis, control of, 593
Parathion, effect on
soil flora, 303
soil treatments on strawberries, 859

various stages of two-spotted spider mite, 791
Parathion, for control of
Acontia dacia, 1150
Agrotis sp., 362
Anopheles crucians, 629
apple maggot, 479, 732
boll weevil, 753
bollworm, 753
cabbage looper, 937
California red scale, 100
carrot rust fly, 362
cherry fruit fly, 746
clover leaf weevil, 927
clover root borer, 328
codling moth, 161, 732, 770, 936, 1095
common malarial mosquito, 629
corn earworm, 94, 364
cotton aphid, 753
cotton fleahopper, 753
cotton leafworm, 542
cranberry fruitworm, 519
desert damp-wood termite, 366
Empoasca solana, 534
Erythroneura lawsoniana, 362
European apple sawfly, 733
garden springtail, 174
greenhouse whitefly, 531
green peach aphid, 538
grasshoppers in Mexico, 98
house fly, 439, 978
lesser peach tree borer, 911
lygus bugs, 705
Maruca testulalis, 533
meadow spittlebug, 844
Melanotus communis, 342
mites, 32, 595, 714, 753, 867, 870, 1005, 1021
olive scale, 287
onion maggot, 495
onion thrips, 617
orange tortrix, 163
oriental fruit moth, 148
pea aphid, 491
peach tree borer, 360, 911, 912
pecan nut casebearer, 714
pepper weevil, 1142
periodical cicada, 244, 459
pine needle scale, 499
plum curculio, 731, 909
potato leafhopper on peanuts, 261
root maggots, 609
rosy apple aphid, 733
serpentine leaf miner, 538
Simulium downsi, 139
soft scale, 1132
southwestern corn borer, 708
striped cucumber beetle, 807
tobacco budworm, 172
tomato fruit worm, 538
western grape leaf skeletonizer, 56
yellow clover aphid, 1157
Parathion, toxicity of, to
native elm bark beetle, 745
smaller European elm leaf beetle, 745
tobacco hornworm, 215
Paregle
cinerella, 251
radicum, 558
Parlatoria oleae, 7, 39, 287
Parlatoreopsis, sp., 40
Pea virus spread, reduction of by insecticides, 490
Peach insect control, 354, 909
Peanuts, effect of insecticides on yields of, 1113
Pectinophora gossypiella
control of, 177, 1022
response to lights, 81
Pediculus humanus humanus, 183, 501
Pegomya sp., 558
Pentatomidae, crossbreeding experiments, 377
Pentachlorophenol, on calves, 1145
Perezia pyraustae, on European corn borer, 641
Periplaneta americana, 27, 183, 578, 723, 798
Perthane (see Q-137)
Phaenicia
caeruleiviridis, 249, 410, 418, 558
cluvia, 410
pallescens, 247, 410, 557
sericata, 247, 407, 410, 418, 557, 1056
Phaeogenes hariolus, 589
Phaonia sp., 558
Phaseolus virus 2, 1121
Phenacaspis pinifoliae, 498
Philaenus leucophthalmus, 313, 842, 927
Phyctaenia rubigalis, 188
Phorophora
confinnis, 676
discolor, 676
regina, 249, 410, 441, 557
Phosphorus
compounds in house fly baits, 335
radioactive, in house flies, 973
Phyllocoptruta oleivora, 20, 23
Phyllophaga, 1092
prununculina on pine seedlings, 710
Phytophthora infestans in potato, 538
Phytoseius spoofi, 176
Phytotoxicity of insecticides, 735
Phryxe pecosensis, 589
Phytophaga destructor, wheat resistant to, 1038
Pieris rapae, 188, 564, 993
Piesma quadrata, 212
Piperonyl butoxide in house fly control, 88, 664, 701
Piperonyl cyclohexenone, for control of
turnip aphid, 782
Planococcus citri, 211
Plant quarantine in Okinawa, 703
Platynota flavedana, 941
Plodia interpunctella, 97, 282, 464
Plutella maculipennis, 188, 277, 993
Poecilographus sp., 558
Podisus maculiventris, 683
Polychrosis, botrana, 22, 23
Polymerus basalis, 683
Polynema, 786
Polyphylla 10-lineata, 717
Polyplax serrata, 443
Popillia japonica, 165, 189, 349, 707
Populations of European chafer larvae, 811
Porthetria dispar, 321
Potasan, for control of
Anopheles crucians, 629
azalea bark scale, 499
codling moth, 772, 1094
common malarial mosquito, 629
oystershell scale, 498
tests with pyrethrum synergists, 73
Prodenia litura, 22, 23
Production sources of house fly, 245
Prospaltella, 39
Protectants
dust, for shelled corn, 462
grain, effect on germination, 706
Protein hydrolysates and B vitamins, 154
Protoparce
quinquemaculata, 879
sexta, 13, 215, 879
Psallus seriatus, 543, 683, 753, 1149

Pseudaletia unipuncta, 188
Pseudococcus citri, 22, 23, 174
Psila rosae, control of, 362
Psoloessa delicatula, 936
Psyllobora taedata, 683
Pyrausta nubilalis, 188, 276, 295, 641, 1015, 1074
Pyrenone Protectant T-483, for stored-grain insects, 464
Pyrethrin-sulfoxide on calves, 1145
Pyrethrum, for control of
  corn earworm, 364
  house fly in food plants, 88
  meadow splittlebug, 844
  turnip aphid, 782
Pyrethrum
  apparatus for determining repellency when applied to grain, 1104
  mixtures, effect of sesamolin, sesamin, and sesamol in, 839
  synergism with nicotine, 219
  tests with synergists, 73
Pyridine, for control of corn earworm, 364

Q-137 (Perthane), for control of
  apple maggot, 479
  beet leafhopper, 123
  codling moth, 771, 1096
  cranberry fruitworm, 519
  horn fly, 267
  meadow spittlebug, 844
  onion thrips, 617
  orange tortrix, 164
  pea aphid, 716
  pepper weevil, 1143
  striped cucumber beetle, 807
  vinegar flies, 921
Q-137, toxicity of, to tobacco hornworm, 216

R-242, against two-spotted spider mite, 791
R-242, for control of
  mites, 32, 867
  Paratetranychus pratensis, 595
  Tetranychus hicoriae, 714
Radioactive allethrin, synthesis and chromatic purification of, 1066
Radioactive material, use of
  calcium-45, 406
  C^{14}-labelled DDT in house fly studies, 1058
  cobalt-60, 929
  dl-cis, trans-C^{14}-allethrin, 1066
  iodine-131, 406, 928
  phosphorus-32, 406, 430, 514, 749, 750, 830, 928, 973, 1045
  P-32-labeled schradan, 903
  Systox and sulphur-35, 446, 684, 1045
Radiation, visible, response of moths to, 81
Repellency, toxaphene and parathion to *Nomia*, 539
Repellents
  against ticks, 13
  all-purpose mixture, 18
  combinations of insecticides, to honey bees, 717
  for control of corn earworm, 364
Residues of
  chlordane and lindane, 332, 1056
  DDT on elms, 626
  dieldrin in oranges, 1033
  insecticides on peaches, 190, 909
  of lindane-chlorinated terphenyl, 332
  malathion on vegetables, 183
Resistance,
  cotton insects to insecticides, 981
  crop plants to insects, 1036
  German cockroach to chlordane and TEPP, 254
  house fly to aldrin, 990
  house fly to DDD, 990
  house fly to DDT, 129, 984
  house fly to dieldrin, 253, 990
  house fly to lindane, 130, 990
  house fly to methoxychlor, 990
  house fly to pyrethrins, 130, 990, 1140
  sorghums to chinch bug, 536
  tumid spider mite to parathion, 982
  walnut aphid to parathion, 366
Resistance to DDT by
  cabbage looper, 564
  Drosophila melanogaster, 387, 393
  Erythroneura lawsoniana, 361
  Erythroneura variabilis, 238
  house flies, 973, 984
  imported cabbageworm, 564
  Lygus, 704
Resistance to insecticides
  Anopheles quadrimaculatus, 580
  mosquitoes, 386
  Oryzaephilus surinamensis, 583
  Periplaneta americana, 578
  variation in, 586
Resistance to lindane by *Blattella germanica*, 254
Reticulitermes flavipes in New York, 661
Reuteroscopus ornatus, 683
Rhagoletis
  cingulata, 8, 746, 959
  pomonella, 479, 732
Rhinacloa forticornis, 683
Rhizopus nigricans, 369
Rhodnius prolixus, 170
Rhopalosiphum pseudobrassicae, 775, 780
Rhyacionia buoliana, 299, 801
Rhynchaenus rufipes, control of, 263
Rhyzopertha dominica, 22, 282, 630, 705, 923, 1106
Rileymyia adusta, 526
Rioxa pornia, 154
Rotenone, for control of
  garden springtail, 174
  green peach aphid, 781
  house fly, 439
  meadow spittlebug, 844
  olive scale, 290
  pea aphid, 716
  potato leafhopper on peanuts, 259
  privet mite, 456
  Putnam scale, 624
  striped cucumber beetle, 807
  tobacco thrips on peanuts, 259
  turnip aphid, 782
Rutabaga, control of maggots in, 607
Ryania, for control of
  cabbage aphid, 993
  cabbage caterpillars, 993
  codling moth, 771
  cranberry fruitworm, 519

Sabadilla, for control of
  cotton leaf perforator, 942
  meadow spittlebug, 844
  potato leafhopper on peanuts, 259
  tobacco thrips on peanuts, 259
Salt cedar, insects on, 1126
Sanninoidea exitiosa, 359, 909, 912
Sarcophaga
  bullata, 410, 418
  errabunda, 410
  haemorrhoidalis, 407, 410, 558
  impair, 407
  spp., 247
  sueta, 410, 418

Scambus hispae, 589
Scaphoideus luteolus, 624, 658
Schoenobius incertellus, control of, 186
Schradan, for control of
beet leafhopper, 123
corn earworm on peanuts, 1112
fall armyworm on peanuts, 1112
meadow spittlebug, 844
mites, 32, 595
Simulium downsi, 139
tobacco thrips on peanuts, 1112
Schradan
metabolism of by plants and insects, 64
methods for residue analysis, 66
mode of action of treated plants, 69
relation of activation in plant tissues to toxicity to insects and mites, 902
toxicity of treated plants to mammals, 67
Scolothrips sexmaculatus, 596
Scolytus multistriatus, 626, 739
Scopeuma
furcata, 558
stercoraria, 558
Screening fumigants for oriental fruit fly, 549
Scymnus
collaris, 683
creperus, 445, 683
haemorrhous, 445
loewi, 683
Seasonal abundance of aphids on greens crops, 775
Seed treatments
for control of onion maggot, 852
of wheat for wireworm control, 597
Seius (*Seiulus*) *pomi*, 356
Seiulus pomi, predacious on European red mite, 176
Simulium downsi, screening chemicals for, 135
Siphona irritans, control of, 35, 79, 80, 266
Sitona cylindricollis, influence of sweet clover stands, 117
Sitophilus
granarius, 20, 282, 464, 630, 705, 923
oryza, 22, 282, 630, 705, 923, 1106, 1124
Sitotroga cerealella, 630, 1124
Sodium fluoride, for control of house fly, 439
Sodium fluosilicate, for alfalfa snout beetle, 637
Soil treatments for *Melanotus communis*, 342
Solubea pugnax, 683
Sparganothis sulfureana, 277
Sphenarium purpurascens, exposure to insecticides, 98
Spiders, effect of insecticides on, 543
Spilonota ocellana, 402
Stegobium paniceum, 282, 923
Stephenitis rhododendri, control of, 263
Stethorus
punctum, 660, 731
sp., 193
Stilpnotia salicis, 939
Stomoxys calcitrans, 35, 249, 558, 940
Strawberries, soil insecticides effect, 859
Strobane, for control of
apple maggot, 479
boll weevil, 754, 805
bollworm, 754
codling moth, 771, 1094
cotton aphid, 754
cotton flea hopper, 754
house fly, 439
spider mites, 754, 805
Sulfotepp, for control of
Anopheles crucians, 629
common malarial mosquito, 629
Simulium downsi, 139
Sulfur, for control of
boll weevil, 753
bollworm, 753
cotton aphid, 753
cotton flea hopper, 753
European red mite, 732
mites, 443, 714, 1005
pea aphid, 716
potato leafhopper on peanuts, 259
spider mites, 753
tobacco thrips on peanuts, 259
yellow clover aphid, 1157
Sulfoxide, synergistic action of, 27
Sulphoxide-pyrethrins, for horn fly, 267
Susceptibility to infective beet leafhoppers by cantaloup plants, 42
Synanthedon pictipes, 359, 908
Synergism, nicotine and pyrethrum, 219
Synergistic action of sulfoxide, 27
Synthesiomyia nudiseta, 410
Syntomosphyrum sp., 589
Synxenoderus, 1144
Systox (see also demeton)
behavior of its isomers in plants, 1045
effect of weather on control of mites, 520
toxicity of isomers to, citrus red mite, 1053
translocation of in cotton plant, 684

Tamarix gallica, insects on, 1126
TDE, for control of
apple maggot, 732
cabbage aphid, 993
cabbage caterpillars, 993
clover root borer, 328
codling moth, 161, 732, 1095
cranberry fruitwork, 519
European apple sawfly, 733
European red mite, 732
house fly in food plants, 88
pepper weevil, 1143
periodical cicada, 244, 459
plum curculio, 731
rosy apple aphid, 733
Simulium downsi, 139
striped cucumber beetle, 807
tobacco budworm, 173
tobacco flea beetle, 348
western grape leaf skeletonizer, 56
TDE, toxicity of, to tobacco hornworm, 215
TDTP, for control of striped cucumber beetle, 807
Temperature
cold, tolerance of European pine shoot moth, 801
studies in bumble bee domiciles, 847
Tenebroides mauritanicus, 282
Tenebrio molitor, 464
Tenuipalpus
bioculatus, 449
inornatus, 449
pseudocuneatus, 450
Teosinte and stored grain insects, 630
TEPP, for control of
azalea bark scale, 499
codling moth, 773
green peach aphid, 781
house fly, 338, 439
pea aphid, 716
peach silver mite, 868
periodical cicada, 244, 458
Simulium downsi, 139
turnip aphid, 782
Termite prevention in New York, 661
Terphenyl, chlorinated, joint action with lindane and with allethrin, against house fly, 796

Tetranychidae, 744
Tetranychus
atlanticus, control on legume crops, 30
bimaculatus, 30, 188, 356, 460, 514, 658, 717, 731, 753, 789, 803, 945, 1084
desertorum, 753, 803, 827, 1084, 1149
hicoriae, 713, 931
mcdanieli, identity of, 460
pacificus, 176, 460
sexmaculatus, 356
sp., 369
telarius, 1086
tumidus, 982
Tetrastichus sp., parasite of seed midge, 146
Therioaphis ononidis, on alfalfa, 1157
Thermobia domestica, digestive enzymes of, 187
Thiram in maggot control, 853, 1041
Thrips tabaci, control of, 616
Thyanta custator, 683
Thysanus, 39
Ticks, 425, 426
Tineola biselliella
cultures attacked by mites, 93
effect of cedar chests on, 1108
TM 341, for control of periodical cicada, 458
TM 12008, for control of
boll weevil, 1148
cotton aphid, 1149
cotton leafworm, 1149
cotton fleahopper, 1149
cotton leaf perforator, 1149
desert spider mite, 1149
flower thrips, 1149
salt-marsh caterpillar, 1149
TM 12009, for control of
boll weevil, 1148
cotton aphid, 1149
cotton fleahopper, 1149
cotton leaf perforator, 1149
cotton leafworm, 1149
desert spider mite, 1149
flower thrips, 1149
salt-marsh caterpillar, 1149
TM 12013, for control of
boll weevil, 1149
cotton aphid, 1149
cotton fleahopper, 1149
cotton leaf perforator, 1149
cotton leafworm, 1149
desert spider mite, 1149
salt-marsh caterpillar, 1149
Toxaphene, effect on
boll weevil, 48, 647
cotton insects, 681, 983, 984
deer fly, 361
insects when fed to cattle, 35
native elm bark beetle, 745
salt-marsh caterpillar, 649
smaller European elm bark beetle, 745
soil flora, 303
tobacco hornworm, 215
Toxaphene, for control of
Acontia dacia, 1150
alfalfa weevil, 313
Apsylla cistellata, 564
boll weevil, 177, 753, 805, 825, 828, 870, 1130
bollworm, 753, 825, 828, 870, 1130
cabbage looper, 937
clover leaf weevil, 927
clover root borer, 328
cotton aphid, 753, 805
cotton flea hopper, 753
cotton leafworm, 542
cotton leaf perforator, 942
corn rootworm, 651
Empoasca solana, 534
flower thrips, 1130
grasshoppers in Mexico, 98
greenhouse whitefly, 531
horn fly, 267
house fly, 88, 439
human bot fly, 540
lice on cattle, 1152
lygus bugs, 705
Maruca testulalis, 533
meadow spittlebug, 314, 844
Meligethes seminulum, 129
onion thrips, 617
pea aphid, 716
pepper weevil, 1142
pink bollworm, 177
potato leafhopper on peanuts, 257
privet mite, 456
rice water weevil, 678
Simulium downsi, 139
strawberry weevil, 1150
southwestern corn borer, 708
spider mites, 753, 805
spiny bollworm, 368
striped cucumber beetle, 807
sugarcane beetle, 1155
tobacco budworm, 172
tobacco thrips on peanuts, 260, 1112
tomato russet mite, 1005
Trombicula spp., 430
turnip aphid, 782
yellow clover aphid, 1157
Toxaphene
phytotoxicity of on trees, 737
repellency of, to *Nomia*, 539
resistance of cotton leafworm to, 981
Toxoptera graminum, grasses as hosts of, 1151
Translocation of Systox, 684
Transmission of bean yellow mosaic virus, 1121
Trialeurodes vaporariorum, control of, 530
Triatoma
gerstaeckeri, altitude tolerance of, 232
infestans, 170
protracta, 170
Triatominae, 426
Tribolium
castaneum, 464, 630
confusum, 22, 183, 282, 404, 464, 630, 923
sp., 1104
Trichlorobenzene, for peach tree borer, 911
Trichogramma minutum, 588, 698
Trichopepla semivittata, 683
Trichoplusia ni, 564, 937, 993
Tripterygium wilfordii, toxicity of, to insects, 188
Tritoxa flexa, 852
Trogoderma
granarium, 22
sternale, 282
Trombicula
akamushi, 430
alfreddugesi, 1153
deliensis, 430
splendens, 1153
wickmanni, 432
Trombiculid mites, 426
Trypanosoma cruzi, 170, 233
Tuberculatus ulmifolii, 658
Turpentine, for control of corn earworm, 364
Tween 20, 465
Tween 80, 13, 19
Tydeus californicus, 356

Typhaea stercorea, 464
Typhlocyba pomaria, 733
Typhlodromus
conspicuus, 356
fallacis, 660
finlandicus, 356
longipilus, 176, 356
masseei, 357
pomi, 357
rhenanus, 176
similis, 357
spp., 356, 1003

Ultraviolet radiation, response of moths to, 81
Urophora jaceana, 401

Vasates
cornutus, 866
lycopersici, 1001
Vector-pathogen combinations, 422
Vectors, of plague, control of on ground squirrels, 604
Vegetation, border treatment for melon fly, 226
Vespa orientalis, 22, 23

Walchia, 434
Weather factors, effect of, on
aphid abundance on greens crops, 775
aphid control, 784
insecticide toxicity, 646
Wheat, effect of protectants on germination, 706
Wireworms
attacking corn, control of, 863
control of in wheat by seed treatment, 597
laboratory tests for control of, 341

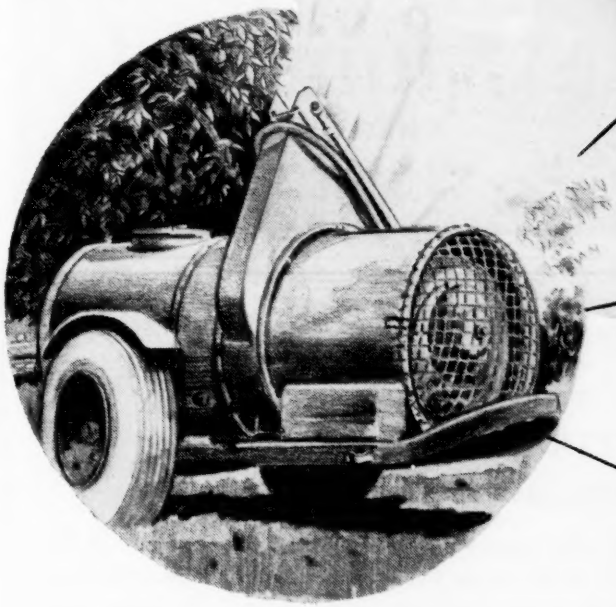
Xerophloea vanduzeei, 211

Zabrotes pectoralis, 923
Zeuzera pyrina, 23

Stauffer Insecticides

*MAXIMUM STABILITY
*GREATEST RANGE OF COMPATIBILITY
IN THE SPRAY TANK

"Stauffer *insecticides* . . .
first among growers
second to *none!*"



DDT
50-75% POWDERS
A microfine wettable powder which has been stabilized to give greater compatibility in tank mixtures with other spray materials.

PARATHION
15% POWDERS
Stabilized formulation of Parathion. The 15-W in a dustless wettable powder for greater safety.

WETTABLE POWDERS
BHC
LINDANE

AND NOW!
DIELDRIN
50% Wettable Powders
for plum curculio and "cat-facing" insects on peaches and apples!

Stauffer CHEMICALS
SINCE 1885

"Stauffer insecticides . . .
the sure way, to be sure!"

Send now for complete information on the full uses of these and other Stauffer insecticides. Or consult your local distributor.

STAUFFER CHEMICAL CO.
380 Madison Avenue, New York 17, New York
221 N. La Salle Street, Chicago 1, Illinois
824 Wilshire Blvd., Los Angeles 14, California
636 California St., San Francisco 8, California
Houston 2, Texas • Weslaco, Texas • Apopka, Florida • N. Portland, Oregon

Now... it's
FAIRFIELD Pyrenone*
the new
FAIRFIELD
CHEMICAL DIVISION
of
Food Machinery
& Chemical Corp.
the famous insecticide
concentrate based on
Pyrethrins and Piperonyl Butoxide:
• Effective against a wide range of insects
• Economical
• Free from toxic hazards
Same product, same personnel, same production facilities — transferred from U. S. I. Chemicals Co. Division of the National Distillers Products Corporation, effective Sept. 1, 1954.
fairfield
CHEMICAL DIVISION
Food Machinery & Chemical Corporation
420 Lexington Avenue, New York 17, N. Y.
*Reg. U.S. Pat. Off., P.M.C.

Announcing . . .

REVISION OF THE SPIDER MITE FAMILY TETRANYCHIDAE

By A. Earl Pritchard and Edward W. Baker

This world-wide treatment (300 pp., 330 figs.) of the "Red Spider" is the second volume in the Memoirs Series of the Pacific Coast Entomological Society. Each species is beautifully illustrated in the inimitable style of E. W. Baker. The work deals with the systematics, identification, and economics of the "Red Spiders". Synoptic keys have been prepared, descriptions are presented for all the species including the major agriculture pests, and some twenty species are described as new.

Publication date December, 1954

Publication Price: $10.00

Send orders to:

Treasurer, Pacific Coast Entomological Society
CALIFORNIA ACADEMY OF SCIENCES
Golden Gate Park 18, San Francisco

PANASOL

INSECTICIDE SOLVENTS

A dependable source of high boiling aromatic solvents for the preparation of insecticide concentrates.

Available from inventory for prompt shipment.

Samples and information available.

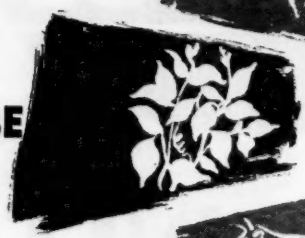
PAN AMERICAN CHEMICALS

PAN AMERICAN Chemicals
DIVISION
Pan American Refining Corp.
122 EAST 42ND STREET • NEW YORK 17, N. Y.

whether it's . . . .

APHIDS IN THE ALFALFA

BEETLES IN THE BE



LICE ON THE LIVESTOCK

Specify

GEIGY AGRICULTURAL CHEMICALS

THEY'RE EFFECTIVE, DEPENDABLE, AND ECONOMICAL!

ALDRIN (dusts, wettable powder, spray)
ARAMITE* (dusts, wettable powder, spray)
ARSENICALS
BHC (dusts, wettable powder, spray)
CARBAMATES (dusts, wettable powders)
CHLOROBENZILATE (338) (dust, wettable powder, spray)
CHLORDANE (dusts, wettable powder, sprays)
COPPER FUNGICIDES
DDT (dusts, wettable powders, sprays)
DIELDRIN (dusts, wettable powders, spray)
FUMIGANTS
HEPTACHLOR (dusts, wettable powder, spray)
LINDANE (dusts, wettable powders, spray)
MALATHION (dusts, wettable powder, spray)
METHOXYCHLOR (dusts, wettable powder, spray)
PARATHION (dusts, wettable powders, spray)
PCP
ROTENONE (dusts, wettable powder)
SEED DISINFECTANTS
SEQUESTRENE† **METAL COMPLEXES**
SULPHUR (dust, wettable powder)
TDE (DDD) (dusts, wettable powder, spray)
TEPP
TOXAPHENE (dusts, wettable powder, sprays)
WEED AND BRUSH KILLERS
SPECIALTIES (for home and garden)

*Trademark U. S. Rubber Co.
†"SEQUESTRENE" is the brand name for chelating compounds produced by Alrose Chemical Company, a Geigy Company.

ORIGINATORS OF DDT INSECTICIDES

Geigy

GEIGY AGRICULTURAL CHEMICALS

89 BARCLAY ST., NEW YORK 8, N. Y.

Division of Geigy Chemical Corporation

Aberdeen, N. C.; Burlington, Iowa; Elkton, Md.; Fresno, Calif.; Houlton, Me.; Leland, Miss.; McGregor, Tex.; Orlando, Fla.; Yakima and Walla Walla, Wash.

. . . the leading carrier and diluent

SOURCE—Attapulgite, a hydrous aluminum magnesium silicate.

COLOR—Cream.

HARDNESS—Degritted, non-abrasive. Does not induce abnormal wear on grinding, mixing, spraying or dusting equipment.

BULK DENSITY—27-31 lbs./cu. ft. in a packed condition.

FINENESS—1-2 microns (surface mean diameter, by air permeation method).

pH—Neutral. Broad usage has shown no effect on acid- or alkali-sensitive materials.

ADSORPTIVITY—Large capacity to accept and carry various types of toxicants. Makes dry, lump-free mixtures containing 50% DDT; 50%, 75% and 85% BHC, depending on gamma content; 40% toxaphene; 40% and 50% chlordane; 15%, 25% and 40% parathion; 25% aldrin; 25% dilan; 25% lindane; 15% and 25% aramite; 25% heptachlor.

WETTABILITY—Inherent wettability effects savings on wetting agents.

SUSPENSIBILITY—Wettable powders containing Attaclay readily disperse to form a satisfactory suspension.

FLOWABILITY—Accepts high percentages of difficult-to-process toxicants yet stays lump-free. Flows loosely during and after formulation and after long periods of storage, even under adverse conditions.

DUSTABILITY—Attaclay-mixed dusts are noted for their ability to flow, disperse, settle, cover and adhere.

CONDITIONING ABILITY—When used as a conditioner, Attaclay makes dusts freer flowing. Adjusts bulk so that entire line of dusts has near-uniform volume. This permits standardization of container size and minimizes rate adjustments on dusters.

COMPATIBILITY—Well established through commercial formulations with DDT, BHC, chlordane, toxaphene, parathion, lindane, aldrin, dieldrin, dilan, aramite, heptachlor, rotenone, sulfur, basic copper sulfate, carbamates, nicotine, 2,4-D, and naphthenate type plant hormones.

USES—Insecticide and fungicide dust bases, wettable powders and finished dusts. Carrier for impregnated liquid toxicants. Conditioner for finished formulas. Anti-caking agent.

We invite you to put Attaclay to your most exacting tests.
Generous samples and technical assistance upon request.

SOIL PESTICIDE GRADES

Attapulgus Clay is available in granular grades for the formulation of soil pesticides. Write for samples and data sheet.

ATTAPULGUS DIVISION
MINERALS & CHEMICALS
CORPORATION OF AMERICA

Dept. T, 210 West Washington Square, Philadelphia 5, Pa.

Powco Brand

Basic Materials and Concentrates

for Insecticide–Rodenticide–Herbicide Manufacturers

DDT INSECTICIDES

Dust Concentrates—Wettable Powders—Emulsions—Oil Soluble Concentrates

CHLORINATED INSECTICIDES

BHC, Lindane, Chlordane, Toxaphene---Dust Concentrates—Wettable Powders — Emulsions — Oil Soluble Concentrates

BOTANICALS

Pyrethrum, Rotenone, Sabadilla---Dust Concentrates — Emulsions — Oil Soluble Concentrates

RODENTICIDES

Antu—
J P 50 M (50% D D T tracking powder)

ORGANIC INSECTICIDES

Parathion, TEPP, Malathion, Allethrin, Aldrin, Dieldrin, Dilan, Heptachlor---Emulsion Concentrates—Dust Concentrates—Wettable Powders.

ORGANIC WEED KILLERS

2, 4-D., 2, 4, 5-T---Acids, Salts, Emulsions, Oil Soluble Concentrates

SPECIALTY ITEMS

Aerosols
Custom made formulations—Grinding to meet specifications

POWCO BRAND
KILLING POWER—THAT'S THE THING!

John Powell & Company

Division of Mathieson Chemical Corporation
One Park Avenue, New York 16, N.Y.
Sales Offices: Philadelphia · Pittsburgh · Chicago · Fort Worth · Omaha · San Francisco · Atlanta
Representatives in Principal Cities of the World

DDT · Toxaphene · BHC · Chlordane · Lindane · Rotenone · Sabadilla · Pyrethrum & Pyrin · Antu · Piperonyl Butoxide · Malathion · Allethrin · Tepp · Parathion · Aldrin · Dilan · Heptachlor · 2, 4-D & 2, 4, 5-T.

LOOK TO POWELL . . . FOR CONSISTENT, TROUBLE-FREE QUALITY

two great insecticides . . .

CHLORDANE

CONTROLS THESE INSECTS

Ants, Armyworms, Blister Beetles, Boxelder Bugs, Brown Dog Ticks, Cabbage Maggots, Cattle Lice, Chiggers, Chinch Bugs, Cockroaches, Cotton Boll Weevils, Crickets, Cutworms, Earwigs, Fleas, Flies, Grasshoppers, Household Spiders, Japanese Beetle Larvae, Lawn Moths, Lygus Bugs, Mole Crickets, Mormon Crickets, Mosquitoes, Onion Maggots, Onion Thrips, Plum Curculio, Sarcoptic Mange, Seed Corn Maggots, Serpentine Leaf Miners, Sheep Ked, Silverfish, Sod Webworms, Southern Corn Rootworms, Strawberry Crown Borers, Strawberry Weevils, Sweet Clover Weevils, Tarnished Plant Bugs, Termites, Ticks, White Grubs, Wireworms . . . *and many others*

HEPTACHLOR

CONTROLS THESE INSECTS

Alfalfa Weevils, Ants, Argentine Ants, Cotton Boll Weevils, Cabbage Maggots, Chinch Bugs, Corn Borers (European), Corn Rootworms, Cotton Thrips, Cowpea Curculio, Crickets, Cucumber Beetles, Cutworms, European Chafer, Eye Gnats, Fleas, Flea Beetles, Garden Webworms, Grasshoppers, Japanese Beetles, Leaf Miners, Lygus Bugs, Mormon Crickets, Mosquitoes, Narcissus Bulb Flies, Onion Maggots, Onion Thrips, Plum Curculio, Rapid Plant Bugs, Screwworms, Seed Corn Maggots, Serpentine Leaf Miners, Spittle Bugs, Sugar Beet Root Maggots, Sweet Clover Weevils, Tarnished Plant Bugs, Tobacco Flea Beetles, Tomato Fruitworms, Tuber Flea Beetles, Turnip Maggots, Western Harvester Ants, White Grubs (June Beetles), Wireworms . . . *and many others.*

WRITE FOR FULL PARTICULARS

VELSICOL CORPORATION

Division of Arvey Corporation

General Offices and Laboratories
330 East Grand Avenue, Chicago 11, Illinois

Export Division
100 East 42nd Street, New York 17, New York

REPRESENTATIVES IN PRINCIPAL CITIES

PETROLEUM DERIVED CHEMICALS
VELSICOL
SERVING BASIC INDUSTRIES

For Insecticides...

DIAMOND ALKALI COMPANY, long associated with high-quality chemicals, is one of the world's largest manufacturers of basic insecticides and herbicides. The name DIAMOND, itself, is your automatic assurance of the best the market has to offer.

DDT	100% Technical
BHC	36% Technical
K-101	Acaricide
Hexachloro-benzene	Seed Disinfectant
*LINDANE	99% Gamma Isomer of BHC

*This practically odorless insecticide kills three ways — by vapor, contact and stomach action. Economical LINDANE goes to work as soon as applied — and continues to kill because of its good residual action. Remarkably effective for *seed treatment* at planting time, too.

think first of DIAMOND

DIAMOND ALKALI COMPANY
Organic Chemicals Division
80 LISTER AVE., NEWARK 5, NEW JERSEY

DIAMOND ALKALI CHEMICALS

Plants: Newark, N. J., Houston, Texas

Chemicals you live by

. . . use CELITE

BY USING Celite powder to absorb liquid poison, you can obtain the most highly concentrated dust and, at the same time cut packaging and shipping costs!

That's because Celite is a diatomite powder with an unusually high liquid absorption capacity. It can absorb its own weight in liquid poison and still remain "dry."

In addition, the presence of Celite in the final dust will help neutralize the effect of heavy extenders . . . thereby insuring better dispersion of the poison. Celite can do this because of its great bulk per unit of weight and the irregular shape of its particles.

Celite gives equally effective results in your primary grinds. It aids grinding of both solid and semi-solid low melting point poisons, and helps make a much more potent dry dust concentrate.

It will pay you to look into the use of Celite as an inexpensive means of improving your product and increasing your profits. For details, write to Johns-Manville, Box 60, New York 16, New York.

Properties of CELITE

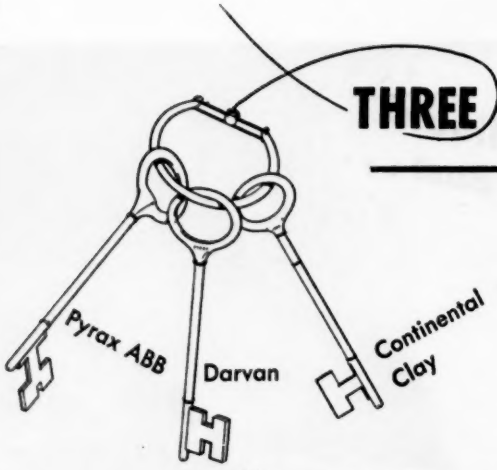
FINENESS: Approximately 100% through 325 mesh
DENSITY (Vibrated): 11 pounds per cubic foot
BULK: Celite bulks much higher than most diluents
ABSORPTION: 200% of its weight of water
300% of its weight of kerosene
pH VALUE: Below 7.0
INERTNESS: Compatible with insecticide and fungicide poisons
SUSPENSION: Excellent in both air and water
COMPOSITION: Celite is amorphous diatomaceous silica (SiO_2)

Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville CELITE

DILUENTS AND GRINDING AIDS



THREE keys for better dusts better sprays

Pyrax ABB

The most widely used Pyrophyllite in the agricultural field, Pyrax ABB is principally applied as a carrier for insecticides and fungicides. Pyrax ABB is also used in lesser quantities in seed protectants, weed control, defoliant dusts, and many other applications.

Pyrax ABB is nonhygroscopic. It may be stored from season to season because it does not affect the toxic strength of DDT, rotenone, pyrethrum, toxaphene, benzene hexachloride, the thiocarbamates, or the newer organic toxicants. Pyrax ABB is chemically inert — pH between 6.5 and 7.0. Free flowing, it mixes quickly and homogeneously giving a more even feed from the hopper, even with the newer waxy and oily toxicants. Pyrax ABB is extremely well adapted for aircraft dusting.

Non-drifting, Pyrax ABB produces a dense cloud that hugs the crop and adheres electrostatically — even to the dry underside of foliage — insuring less waste and permitting effective daytime dusting.

Increased plant capacity now assures an adequate supply of Pyrax ABB.

Darvan #1 and #2

Excellent dispersing and suspending agents for agricultural wettable concentrates. The unusual qualities of the Darvans maintain finely divided solids or liquids dispersed in aqueous medium over long periods of time.

Darvans are soluble in water, with a neutral pH, and stable toward mild acids and alkalis. Characteristically, Darvans break up agglomerates or flocs to their ultimate particle size to produce better dispersions.

Recent tests indicate that very small amounts of Darvan actually increase the effectiveness of toxicant in wettable concentrates. Field tests showed greater crop yields when Darvan was added to the active agent and carrier than when the same carrier and agent were used without Darvan. The addition of Darvan with a wetting agent also increased the yield.

Continental Clay

Continental Clay is recommended as a highly compatible and non-alkaline carrier for your agricultural high bulk dust. Continental is further recommended for wettable concentrates.

For both High Bulk Dusts and Wettable Concentrates, Continental Clay is an economical, top quality carrier of unusually fine particle size (0.8 micron by air permeation and less than 0.75% retention on a 200 mesh screen). Continental is a non-abrasive, extremely flowable carrier for high bulk dust. In wettable concentrates, it is outstanding in qualities of dispersibility and wettability. Continental Clay assures uniformity for all your dry dusts and wettable concentrates. Continental Clay is always available in adequate supply.

Write today for Bulletin No. D23 on Agricultural Dusts and Sprays.

R. T. VANDERBILT CO.

SPECIALTIES DEPARTMENT

230 PARK AVENUE, NEW YORK 17, N. Y.

- ☐ Please send bulletin D23.
- ☐ Please send sample of PYRAX.
- ☐ Please send sample of DARVAN.
- ☐ Please send sample of CONTINENTAL CLAY.

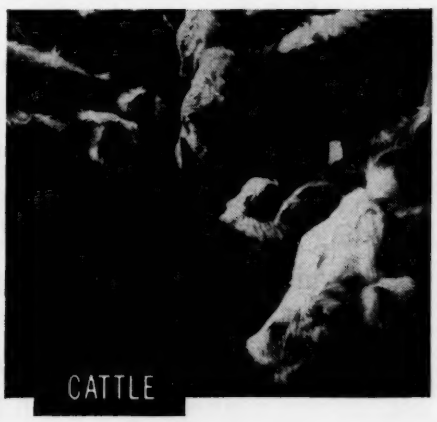
NAME_____

POSITION_____

(Please attach to, or write on, your company letterhead)

TOXAPHENE PROTECTS

FOOD, FEED, AND FIBER CROPS



Wherever you live, it's probable that the crops grown there can benefit from insecticides based on toxaphene (chlorinated camphene 67-69% Cl). Recommended for effective control of more than 150 different species of insect pests, toxaphene dusts and sprays are helping to protect food, feed and fiber crops —to increase yields throughout the world.

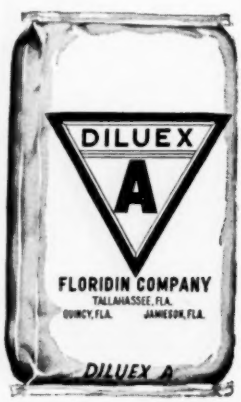
Naval Stores Department
HERCULES POWDER COMPANY
991 Market St., Wilmington 99, Del.

For improved production at little cost

use DILUEX-A *in*

Liquid Toxicant Formulations

This highly adsorbent carrier has been developed by the Floridin Company for the processing of impregnated concentrates. Originally recommended for toxaphene and chlordane formulations, DILUEX-A has found preference for more varied uses. Ease of handling, increased output, and an improved final product commend it in grinding and blending operations. Customer satisfaction confirms the choice. Adequate unfailing supplies of DILUEX-A is a practical consideration. Take a look at the following data and ask for any further information that you would like.



Properties of DILUEX-A

Color: Light grey to cream
Composition: Aluminum magnesium silicate (Florida Fullers Earth)
Bulk: 19 to 21 lbs. per cubic foot, loose
33 to 36 lbs. per cubic foot, packed
Mesh: 90 to 95% finer than U. S. 325
Specific Gravity: 2.2 to 2.4
Surface Mean Diameter: 1.5 to 1.7 microns
pH: 6.8 to 7.1 (AOAC method)
Abrasiveness: Lowest rating
Adsorption: Adequate for impregnating liquid toxicants at recommended concentrations

FLORIDIN COMPANY

Adsorbents . . . . . Desiccants . . . . . Diluents

Dept. R, P.O. Box 998, Tallahassee, Florida

JOURNAL OF ECONOMIC ENTOMOLOGY

ENTOMOLOGICAL SOCIETY OF AMERICA

MANUSCRIPT RULES and SUGGESTIONS

MANUSCRIPT for publication should be sent to the Editor, Dr. F. W. Poos, 1530 P St. N.W., Washington 5, D.C. No manuscript which has been published elsewhere, either wholly or in essential part, will be accepted for publication in the JOURNAL OF ECONOMIC ENTOMOLOGY.

ARTICLES will be published in order of receipt, except for material given priority by committee action or the editor's discretion. Date of receipt will be that date on which copy is accepted in final form for publication, according to the following directions, whether or not it may have been returned to the author for correction. It is therefore to the author's best interest to submit clean copy. Clarity, comprehensiveness and conciseness are most desirable; preferably the paper should be accompanied by the written approval of one or more persons familiar with the subject. The manuscript should be clearly typewritten, double spaced, on one side of the paper only. It should be mailed flat; not folded or rolled. The sheets should not be stapled or pinned. Pages should be numbered correctly. *Author's complete address, to which proof is to be sent, should appear at upper right-hand corner of first page.* Footnotes should be numbered consecutively. Citations should give author, year, title, name of publication, volume, number of issue or month, and page in the order named. Clear, concise headings should be supplied for tables and legends for illustrations. Subheadings intended to be set by themselves in the middle of the page should be avoided. Sideheadings, not more than two per typewritten page, meet most needs. They should be informative, not mere labels or tags.

Prompt publication of acceptable matter may be secured by payment of the cost of printing and engraving. (Ten dollars per page plus engraving with additional charge for excessive tabular material.)

TABLES are expensive. They should always be reduced by authors to the simplest form *and withdrawn if text or illustrations give the same information.* Tables should be arranged so that, regardless of their length, the number of columns is reduced to the minimum. Papers submitted with more tables than seem necessary, or with tables poorly arranged, will be returned to the author for modification.

ILLUSTRATIONS are accepted at the discretion of the Editor only when they contribute materially to the information presented in the paper. Photographs of persons, scenery and machinery of well-known types will not be used unless other special features justify their use. Data should be presented in tables rather than graphs when the nature of the data permits a choice. Graphs should be so constructed that the greatest dimension is *vertical* rather than horizontal. Lines on the graphs, as well as letters and figures, should be heavy enough to stand reduction without losing their clearness and waste space on graphs should be kept at a minimum. All graphs larger than the manuscript sheets *must* be reduced, by photographing or otherwise to a size not larger than the manuscript sheets and should be mailed in the package with the manuscript.

Graphs should be drawn on blue cross-hatched paper or white paper for satisfactory reproduction. Tracing paper or cloth is satisfactory where there may be an advantage in its use. Orange cross-hatched paper is unsatisfactory for reproduction. Thermograph charts do not reproduce satisfactorily. Good photographs when they can be obtained should accompany obituaries. Used engravings may be secured by authors who desire them if application is made to the editor within 60 days of their publication.

Legends of figures should never be made a part of the copy. They should be typed in the proper place in the manuscript and identified by the figure number.

Each piece of copy for engraving should bear on its back the name of the author and the title of the article which it is to accompany as well as the figure number corresponding to that used with the legend in the text.

SCIENTIFIC NOTES and OBITUARIES as well as short entomological notes suitable for use as "fillers" on short pages, should be sent to the editor. Reports of meetings of Branches of the Association and of other Entomological Organizations should also be sent to the Editor.

REPRINTS

Price Schedule—Transportation Costs to be added.

Pages	1	2	3-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	Covers
50 copies*	$3.75	$4.00	$4.25	$6.00	$ 8.55	$ 9.35	$12.10	$14.00	$16.35	$17.35	$6.10
100 copies	4.00	4.35	5.05	7.00	10.30	11.40	14.55	17.15	19.95	21.40	7.40
Addl. 100's	1.00	1.40	1.60	2.00	3.55	4.10	4.90	6.30	7.25	8.15	2.65

For 500 copies, deduct 5 per cent—For 1000 copies deduct 10 per cent. Folio Reprints no longer available. Changing page numbers, 40¢ per page additional. Remaking pages, 60¢ per page additional. Additional charge will be made on orders specifying extra typesetting, revisions, repaging or special paper.

* No order for less than 50 copies accepted. Handling and billing charges 25¢ per order extra.

ENTOMOLOGICAL SOCIETY OF AMERICA

OFFICERS

President—HERBERT H. ROSS, Urbana, Ill.

President-elect—GEORGE C. DECKER, Urbana, Ill.

Executive Secretary—ASHLEY B. GURNEY, 1530 P. St., N.W., Washington 5, D.C.

GOVERNING BOARD

H. H. Ross, Urbana, Ill.

J. W. APPLE, Madison, Wis.
S. F. BAILEY, Davis, Calif.
P. J. CHAPMAN, Geneva, N.Y.
G. C. DECKER, Urbana, Ill.
M. D. FARRAR, Clemson, S.C.
J. C. GAINES, College Station, Tex.
ASHLEY B. GURNEY, Washington, D.C. (non-voting)
H. M. HARRIS, Ames, Iowa
E. G. LINSLEY, Berkeley, Calif.
R. H. PAINTER, Manhattan, Kan.
C. E. PALM, Ithaca, N.Y.
B. A. PORTER, Washington, D.C.
H. H. SHEPARD, Washington, D.C.
CARROLL N. SMITH, Washington, D.C.

Branch Chairmen

J. D. STEINWEDEN, Los Angeles, Calif.—(Pacific Branch)
W. G. BRUCE, Gulfport, Miss.—(Cotton States Branch)
H. G. WALKER, Philadelphia, Pa.—(Eastern Branch)
T. C. ALLEN, Madison, Wis.—(North Central Branch)
J. M. LANDRUM, Waco, Tex.—(Southwestern Branch)

Branch Chairmen-Elect

WALTER CARTER, Honolulu, Hawaii—(Pacific Branch)
J. G. WATTS, Blackville, S.C.—(Cotton States Branch)
E. H. WHEELER, Amherst, Mass.—(Eastern Branch)
HAROLD GUNDERSON, Ames, Iowa—(North Central Branch)
D. F. MARTIN, College Station, Tex.—(Southwestern Branch)

Branch Secretaries

LESLIE M. SMITH, Davis, Calif.—(Pacific Branch)
W. G. EDEN, Auburn, Ala.—(Cotton States Branch)
BYRLEY F. DRIGGERS, New Brunswick, N.J.—(Eastern Branch)
R. W. RINGS, Wooster, Ohio—(North Central Branch)
C. A. KING, JR., Waco, Tex.—(Southwestern Branch)